# BEET-SUGAR MANUFACTURE

AND

# REFINING

VOL. I.

## EXTRACTION AND EPURATION

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*FIRST EDITION*

FIRST THOUSAND



NEW YORK
JOHN WILEY & SONS
LONDON: CHAPMAN & HALL, LIMITED
1905

ROBERT DRUMMOND, PRINTER, NEW YORK

# PREFACE.

NOTWITHSTANDING the fact that the beet-sugar industry has been in existence for one hundred years, the English literature upon the subject which has been written, not by compilers, but by specialists, is limited to a few monographs.

The Saxon appeared oblivious of the fact that the sugar cane cultivated in the West Indies and other semitropical countries could meet less than one half of the world's constantly increasing sugar consumption.

The very primitive processes for extracting the juice from the cane and the sugar from the juice that have long since been proved money-wasting operations, still continue in vogue in thousands of cases, and this fact has in a measure been the salvation of the beet-sugar industry; for had those methods of working kept pace with the times the beet would not have attained the lead it now has. On the other hand, when all observations have been made, all collected data pertaining to beet sugar become almost obsolete after a time.

More than thirty years ago the author began visiting European beet-sugar factories, and up to the present he has examined the workings of nearly three hundred plants. Thousands of pages of notes were collected in France, Germany and Austria-Hungary; but alas! when these voluminous data were compared the author found so much discord, so many plans, such a variety of processes apparently the same but yet totally different, that he was compelled to abandon the task of attempting to combine the information into one continued whole of value to sugar specialists. Upon the careful examination of the standard works upon beet-sugar manufacture in both French and German, it was noticed that the authors argued from the bias of their respective national standpoints, and

that consequently international readers would be misled if the assertions of one case or another were given as standards to be followed. Dr. CLAASSEN's comparatively recent book, without illustrations or description of machinery, and with very few references for future research, is intended only for those who are thoroughly familiar with the conditions of the beet-sugar industry; and although it forms a most important contribution to the literature upon that subject, it does not cover the field the author had in view. However, it was concluded that when possible CLAASSEN's views should be given. They do not always agree with those of other well-known sugar experts, and in many cases the gist of the argument hangs on such delicate points that it is next to impossible to decide between them. In fact, throughout the entire realm of sugar-manufacturing processes, there is a vast budget of contradictions, many of which are given side by side, thus enabling the reader to draw his own conclusions. In cases where the author's extended experience discovers certain glaring absurdities, decided views have been advanced and the reader may place reliance upon such assertions.

The copious references necessarily represent fountainhead information. There are so many typographical errors in most of the standard sugar publications, that an effort to discover within what limits these references are reliable required a labor of years; and although it is not even now claimed that the author's purpose has been entirely accomplished, he confidently believes that the effort made is a move in the right direction. A simple compilation from other books whereby possible errors are perpetuated only makes matters worse. As has been pointed out in the foregoing, a certain reliance must be placed in the author's technical practice and experience; yet despite his having lived for a quarter of a century in and out of the numerous beet-sugar factories of Continental Europe, there yet remained Belgium, Holland and Sweden, where his experience had been comparatively limited, and as to those places the information given is credited to the distinguished and well-known sugar expert, A. DE MALANDER, whose frequently given views certainly add to the practical value of this book. Upon general principles, it is intended that each authority quoted should take upon himself the full responsibility of the views advanced.

It is to be understood that this writing is from a European standpoint. Little or no mention is made of American factory methods, the author's intention being to avoid any attempt at criticising some very glaring blunders that have been committed,

and to leave to those interested the decision as to the limits within which their factories are being conducted on truly technical lines as admitted by the world's leading experts. Special stress has been placed upon giving very complete descriptions of standard machines and appliances, rather than long technical data that in most cases are destined to be short-lived. Very complicated mathematical calculations have been avoided. Those relating to evaporation and the multiple effect are most simple and, being based upon some well-known physical laws, will certainly be within the grasp of most sugar experts. The practical phases of the sugar-manufacturing methods and processes are the main features of the author's efforts.

The metric system has been adhered to throughout, for it seems irrational to refer to the laboratory analyses in decimal measures, and then to describe the workings of the machinery in feet and inches, exception alone being taken as to area of land, farmers of the United States understanding acres, and having no conception of the meaning of hectares.

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# INTRODUCTION.

## PRACTICAL CONSIDERATIONS RESPECTING THE BEET-SUGAR INDUSTRY.

**Is beet-sugar-making a financial venture?**—We frequently have heard the argument of those prejudiced against beet-sugar manufacture: Why place our money in an enterprise which has not met with more success in America? As we have often before said, and now again repeat, every beet-sugar factory in America which has failed has done so through blunders which would have met with the same result in Europe.

We are convinced that every future beet-sugar-making enterprise which will avoid experimenting, and be properly managed, will pay 10 per cent on the capital invested within five years. The first two years there may not be realized 3 per cent. In beet-sugar-making, like many other enterprises, experience must be gained; this at first may prove costly in beet-sugar manufacture. The main difficulty on commencing is the general and correct raising of the roots by farmers. As soon as this has been solved, the profits are realized with almost a certainty; hence it is not a financial venture.

**Beet-sugar manufacture on a small scale.**—Beet sugar cannot be made profitable unless the factory is of at least 300 tons capacity.

By some the *cider-press* idea has been recommended with the view of popularizing the beet-sugar question among the rural population, but the questions remain, Is the object in view accomplished? Will not the ultimate result be just the opposite to what was expected? Will not those prone to offer every possible objection to the general progress of the beet-sugar industry use their practical influence in declaring that the "stuff" they have tasted

is a very inferior article, without entering into a reasonable detail of the exact "whys and wherefores"? Those small-scale sugar manufacturers of the South frequently find their way North and repeat what they have been doing on some plantation where they have been brought up. With what result? Instead of that delightful aroma which raw cane sugar has, when made in the most primitive way, they find a most revolting concoction possessed of a smell that defies description, and is sufficient to sicken an average mortal. The experience is never forgotten, and that alone is sufficient to do much harm toward the general progress of superior beet-sugar manufacture.

Notwithstanding the fact that we have for thirty years been pointing out that it is a mistake to build small beet-sugar factories, we still find it asserted that in Europe the large plants are the exception. This is not true; for we have visited two hundred and ninety factories in Germany, Austria, France, etc., and in no case was the daily capacity less than 200 tons. We do not think that a single factory has been built during the past ten years that was designed to handle less than 15,000 tons during the campaign. The cost of labor in a 100-ton or a 200-ton factory is about the same; the general running expenses in both cases do not materially differ. Many other facts might also be considered which would favor the large plant. A few thousand dollars saved in starting a beet-sugar factory intending to work only 100 tons a day would soon be squandered in the surplus cost of the manufactured product. If from one ton of beets we extract 100 kg. of sugar, it is an item of considerable moment if the cost of labor for 200 kg. is the same; in other words, if two tons of beets can be worked at the price of one, this saving at the end amounts to many thousand dollars.

It is much to be regretted that so many misleading and very inaccurate statements are made in numerous publications of the country. The sugar-beet industry can be advanced by telling the truth. Past experience and observations have weight notwithstanding many efforts to ignore them.

Some time since a very influential sugar-trade journal of New York printed the following advice to those who contemplated beet-sugar manufacture in this country: "Abandon the building of $500,000 refineries to manufacture white sugar three months of the year. Build $25,000 neighborhood factories to turn beet roots into the lowest grades of raw sugars that will secure Govern-

ment bounty. Let the farmers who raise beets be stockholders in the factory. . . . This is the way the manufacture has been brought to its great prosperity on the Continent (Europe), and the only way it will succeed in the United States, in our opinion. Beet-root agriculture can be made very profitable in almost any State in the Union, but beet-root refineries cannot compete with large established refineries running to full capacity every day of the year."

It would not be possible to manufacture beet sugar under such circumstances for much less than 15 cents per pound.

**Starting beet-sugar factories.**—We have noticed that numerous journals have been giving advice respecting the starting of beet-sugar factories; none of these ideas entirely agree with our own. In one instance it is recommended to push ahead, make contracts with farmers, and when 2000 acres are secured the requisite capital will be forthcoming, provided there is ample water for suitable irrigation. We could give several examples where this has been done in the United States, and the factory not being ready in time, the beets were allowed to rot on the field and an equivalent of $80,000 simply went to waste. Numerous protestations, legal complications and general disgust followed. To build the factory before the beets are assured is also a very common error, and has occurred both in the United States and Canada. The campaign then being necessarily very restricted, the interest on the investment being lost the first year, a very heavy reduction in the profits during the slicing period that follows is the result. In justice to a manufacturer of beet-sugar machinery at least one year should be allowed to permit a thorough study of all the facts that are to be dealt with. The scientific designing of the plant demands that it be adapted to the environment and not the environment to it, which is too frequently the case. The selection of a suitable site always means railroad and water facilities, and, as far as possible, should be in the centre of a farming district that has already been experimented with in beet cultivation, and where farmers have already had some practical experience with this special crop, and who are kindly disposed toward the enterprise and willing to give a helping hand toward its success. We have always recommended that the beet-sugar company rent or own at least 500 acres of land which shall be cultivated by them, forming, as it were, a sort of model experiment station, showing the tiller just what could be done and how to do it. The area in question should mean

for the factory at least 6000 tons of beets, which would help to bridge over any farming difficulty that might present itself. The manufacturer should see that the seed is of a first-class quality, that restrictions be placed upon the kind of fertilizer used, that the requisite agricultural methods for successful sugar-beet cultivation be adopted and that the implements are suited for the purpose. If the tiller has not the money to purchase them, they should be loaned or rented by the sugar company. When the yield per acre is over ten tons and the quality of the resulting roots shows them to contain at least 13 per cent of sugar, general satisfaction prevails and there is no difficulty of renewing the contract the following year. Climatic conditions are frequently unfavorable, and very little money is then made either on the field or at the factory. Such variations may occur with crops in general, and for that reason, as far as beets are concerned, there is no occasion for discouragement. Just how beets should be purchased from the farmer is a very difficult question to settle; the most rational and advantageous for the beet-grower and the manufacturer is a basis depending upon the actual sugar the roots contain. This is the mode of purchase for all the commodities, and there is no possible reason why it should not be applied to sugar beets. The farmer replies to this that superior beets mean a comparatively small yield per acre. It is to be noted that in the long run the tiller finds his compensation. Thirteen tons at $4 per ton means $52; but 9 tons at $6 a ton yield $54. This is not a convincing argument for the practical farmer. Do what one may, the subject finds no solution unless the manufacturer has under his control sufficient area cultivated in beets for an average campaign. As regards a superior beet, it must be noted that it not only gives richer juice, meaning more sugar, but the unit of cost of extraction remains the same for superior and inferior beets; hence there is double advantage. With poor beets the sugar losses during the process of extraction are greater than they are with rich beets. The cost of manufacture, calculated upon a basis of one ton of beets sliced, is about the same in the two cases; hence the working cost per pound of sugar extracted from a poor beet is comparatively greater than with roots having a high polarization.

Beets should remain in the ground as long as possible, thus allowing ample time for sugar elaboration. The question of frost must also be taken into consideration, for late frost kills the young plantlets as soon as they appear above ground, and an early frost ends the possibilities of more sugar being formed in the beet. From a manu-

facturer's point of view, his work actually commences only after the beets are delivered at the factory; but he must, as explained in the foregoing, have first-class raw material to handle, otherwise the practical and financial success of the enterprise becomes a failure.

As the manufacturer would be his own farmer, he could afford to bestow special care upon bunching, weeding, etc.; he could use fertilizers that would lead to the maximum yield and quality, and end by growing his own seed. In conjunction with this idea we have for thirty years recommended that a distillery be built to handle, say, 60 tons of beets per diem for 100 days in the manufacture of a superior alcohol, which would find a ready market. When the beet-sugar factory is built, the distillery could handle the residuary molasses. In the meantime there need be no guesswork of how much the cultivation of beets costs in the selected locality, nor as to the contents of beets in sugar. The alcohol extracted would accurately give the total quantity of sugar contained in 6000 tons, and would not be based upon the analysis of a handful of beets, such calculations being frequently very misleading. The Standard Cattle Company of Nebraska went about their factory in a very practical way. They knew in advance just what the soil would yield and the cost of beets per acre, but they did not accurately know how much sugar 1000 acres—for example—of beets would yield. The beets cultivated were fed to cattle and thus practically disposed of. The method adopted was a correct one and will in the ong run certainly lead to very important financial success. When the time comes for building a factory of, say, 500 tons capacity, and builders are invited to send in their bids, it is not always the cheapest that is the most desirable. Beet-sugar manufacture from year to year undergoes important changes, which result in considerable economy not only in the modes of extraction, but in the percentage of extraction realized; $50,000 additional expenditure in the machinery furnished frequently means one-half per cent more sugar. If 50,000 tons of beets are worked during the campaign, this additional sugar means 250 tons, the money outcome of which is more than sufficient to pay for the supposed excessive expenditure the first year. Certain contractors of beet-sugar machinery whom we could mention live up to the times, reject all obsolete methods, and are consequently at an enormous expense for the construction and designing of new machines and devices. Their prices are high, but certainly profitable in the long run. The subject is too extended to be discussed in full in this writing.

However, we hope in the meantime the few hints given in the foregoing may be followed to the letter.

**Do not be in a hurry to start a beet-sugar factory.**—The craze for building new factories all over the country is spreading; we very much regret to learn that many capitalists have been misled by startling statements made by farmers, such as over 30 tons per acre and 18 per cent sugar. Evidently in the desire to increase the value of their property they often have a temptation to slightly exaggerate the results obtained. Heavy yields per acre are not sufficient. The important facts to know are the sugar percentage and purity coefficient. Argue as one may, farmers are unable to grasp, in hundreds of cases coming under our notice, the importance of moderate yields. Those wishing to invest money had better have a series of experiments conducted at their own expense; they would then have some basis to calculate upon. The results obtained on many farms of agricultural stations are not conclusive, for they are in most cases estimated. We are very much opposed to small experimental patches, for the results obtained on such areas are very misleading. There will sooner or later be a great reaction in the home beet-sugar boom, due to a scarcity of good beets. We would have no trouble in naming several of the existing factories that have great apprehensions regarding their future for this very reason. A well-organized company should make farming part of its business, should control and cultivate sufficient area for an average campaign. The tillers of the neighboring counties would soon offer their services without special favors being asked. In California, Michigan, and other States the farmers continue their complaints as to the injustices, etc., done them at the factory. These complaints in some exceptional cases may be justified, but in most instances they are not. Arbitration is the only way. If the arbitrators cannot agree, then a disinterested person must be called in. In Europe this method is general in most countries we have visited, not only for seed purchase, germination, but beet analysis, weighing, etc., etc.

**Farmers, go slow.**—One of the greatest mistakes made by the farming community who frequently attend meetings intended to develop the beet-sugar interests of this country is that they become over-enthusiastic in many cases. They see a gold mine ahead without considering the numerous struggles necessary in order to reach the goal they have in view. Sugar beets mean more than the average tiller appears to appreciate, notwithstanding the efforts

made by promoters officially representing the interests of sugar. For the present we insist upon it that farmers must go slow in their excellent endeavors at superior sugar-beet cultivation.

**Sugar extracted from inferior beets.**—Certain experts connected with a Western beet-sugar factory claim that they can extract sugar from beets regardless of their purity coefficient.* Every sugar expert can accomplish this, but what they cannot do is to make such extraction profitable to all interested. The methods of purification of juices from inferior beets would cost more than the ultimate sugar would be worth, for the higher the sugar percentage the lower will be the percentage of foreign substances, which offer difficulties to sugar crystallization. Let farmers continue to concentrate their efforts on the cultivation of superior beets, and not, for the present, place much reliance upon the possibility of selling large roots to beet-sugar factories. The manufacturer must make money; if he does not the factory ceases working and the tiller would have to centre his attention in other directions than sugar-beet cultivation. Farmers in furnishing high-testing beets add prosperity to their farms, and it is through careful cultivation that this may be accomplished. Laboratory tests or experiments show that nearly all the sugar may be separated from saccharine juices, but the practice of the factory means a small loss which cannot be overcome by any known process.

**Tearing down and building up of beet-sugar factories.**—From the first effort made to start beet-sugar factories in the United States up to the present day there has been a tendency to remove the plant from one locality to another and to patch up some old sugar plant and calling it a beet-sugar factory. The taking down and building up of beet-sugar machinery has been the curse of the beet-sugar industry in this country. The early factories of California, Wisconsin, etc., were torn down and rebuilt elsewhere. There has not been a single instance where the effort at reconstruction has met with complete success.

**Considerations respecting new factories and the essential changes to existing plants.**—While some installations offer very little attraction from an artistic standpoint, the author considers this a mistake, for the general work to be accomplished is always more willingly done when the environment is agreeable and pleasant to the eye. There is a practical and rational manner of consider-

* At a recent meeting of the German syndicate it was concluded that the purity coefficient be left out in beet analysis.

ing a beet-sugar factory taken as a whole. Some authorities claim that an attractive placing of the machinery so as to produce one grand effect offers many disadvantages from a practical standpoint. Economy of installation can never be realized under such conditions, and this item of surplus capital needed to attain a given result is by some condemned.

A rational installation of a beet-sugar factory means well ventilated, lighted and spacious rooms, allowing its surveillance at a glance. That the machines or apparatus be of the most recent design and constructed in a pleasing manner offers very little interest to the practical and technical manager. When the machines give the requisite power, without an excess of steam in the exhaust pipe, and when the apparatus are properly constructed and yield what is expected of them, they fulfil their purpose. The duties of the technical manager refer to the details of sugar extraction, and this demands careful watching and improvement of all phases of the process depending upon the beet and juice manipulation. As this within itself is all-absorbing, the mechanical features should be looked after by a practical and technical person who understands the whys and wherefores of the situation.

All irregularities in the working of the machines which may be followed by certain perturbations in the general manufacturing methods should be looked after at once, otherwise even greater complications will certainly follow.

All stoppage not only means money, owing, on the one hand, to the fact that during this period there is necessarily considerable labor unemployed, but there follow alterations in the juices and losses of sugar in the beets that must necessarily remain siloed for a longer period.

The more rapidly the juices are worked by avoiding all stoppages in their regular circulation the better will be the final results. It is for this reason that too large a capacity of the appliance of one of the phases of sugar extraction is always a mistake. When such conditions occur they should be decreased or the other appliances enlarged to meet the situation. When an increase of size is made, it is essential to arrange so that this increase corresponds to the other stations of beet-sugar manufacture; otherwise there would follow numerous perturbations during the slicing campaign.

The increase in size of a beet-sugar factory is necessarily the best means of reducing the cost of manufacture; this, however, is true only up to a certain limit. If a beet-sugar factory can ob-

tain all the roots needed, so as to reach its maximum daily capacity the increase in the size of the factory reaches its natural limit when the cost of transportation of the beets which are to be sliced absorbs the economy sought by the contemplated change. Under these conditions it is found more advantageous to build an entire new factory in a more central position. If a factory is enlarged and cannot obtain more beets than before the changes were made the period of the sugar campaign is reduced owing to the increased daily capacity. If the length of the campaign is reduced to about six weeks the increased capacity of the plant will have no practical advantage; but, on the contrary, may be hurtful, as it may happen that the farmers cannot supply the beets in such a short period, and consequently there may follow a stoppage in the general working. In such cases it is better to utilize the means at one's disposal by bringing about an amelioration in the careful work of all the manufacturing details.

When new appliances are added to an existing factory the natural question one asks is, What advantages will be found by their use? In most cases it is essential to demand that there shall follow sufficient gain that the device may pay for itself in less than five years. New inventions are being constantly made, and unless the sinking fund is allowed for one could never be up to the times. It must be noticed that most of the innovations introduced correspond to a special craze or fashion of manufacture that prevails at the time. At one period it may relate to a diffusion, at another to the defecation, evaporation, etc. Those who follow all these changes will end by losing money and derive no profit or advantage. The practical advice is to give any contemplated change all due consideration, and if all issues have been thoroughly weighed and the advantages of the new device are apparent, no time should be lost in making use of it.

The total cost of running a beet-sugar factory for a given period necessarily varies with the plant. On the other hand, the expenses of the fabrication, properly speaking, are always about the same for a factory that has been arranged according to modern modes of working. CLAASSEN gives these details for a German factory, where the fuel and wages are comparatively high. The principal expenses of the campaign for 100 kilos of beets sliced are as follows: Wages, 2.5 to 3 cents; coal for boilers, 2 to 2.5 cents; lime (limestone and fuel), 0.25 to 0.75 cent; filtering cloths, 1 to 1.75 cents; oil, etc., for lubricating, 1 to 1.3 cents.

**Sugar entering factory.**—It is much to be regretted that so much reliance is placed upon the analysis of a few samples of beets for a basis for calculation of the quantity of sugar entering the factory. After the sugar campaign is over there are many surprises awaiting those interested; the difference in the theoretical yield and the practical results obtained are considered the unknown losses, and when these reach important proportions the chemist in charge is blamed for not having watched more thoroughly the different phases through which the juices and syrups have passed. The analysis of the juice taken from the battery is much more reliable, and is the only basis upon which it is possible to form a satisfactory idea of what is to be expected. Factories should have a juice sampler and measurer connected with the diffusion battery. Their working is very accurate; the volumes drawn off at regular intervals are received in a special reservoir, where they are combined with lead acetate and a few drops of bichloride of mercury. A sample of the juice is examined every twelve hours. If 116 liters of juice have been drawn off for 100 kilos of beets and the juice contains 10 per cent of sugar, then $\frac{116\times 10}{100}=11.6$ per cent is the amount of sugar extracted from the beets. If the residuum cossettes retain 0.30 per cent sugar, then the beets contained $11.6+0.3=11.9$ per cent sugar.

**Sugar leaving the factory.**—There are many chemists who continue to estimate the quantity of sugar leaving the factory based upon the first strike *masse cuite;* the calculations are made upon data which are only approximately accurate. The density and composition of the product from the pan may be accurately ascertained, but the volume is an unknown factor; a fraction of an inch in the height of the upper level of the granulated mass in the tanks would mean a véry important error in the final results obtained. Hence the reason why the old method of sugar estimation has been, in many cases, entirely abandoned. The modern methods of graining with return of after product to pan render such methods still more complicated.

An excellent method is to determine the amount of sugar contained in the *massecuite* of second-grade sugars, or, at least, in the syrup swung out from the first-grade sugars; the weight of the latter, added to that contained in the second product from the pan, gives the total amount of sugar leaving the factory. It is very important, however, that the sample to be examined be taken during the period of emptying the pan. It frequently hap-

pens that very small crystals are deposited; hence the importance of a thorough agitation of the sample before the examination.

**Cost of working, etc., in American and European beet-sugar factories.**—The total expenses for any year depend upon the general costs of the administration, sinking fund, and repairs during the summer. The greater the quantity of beets upon which these expenses are distributed the smaller becomes the cost per 100 kilos sliced. It is for this reason that the total cost of administration and manufacture will in one factory be 17.5 to 22.5 cents or more, and in those working an average quantity of beets the cost will be 15 to 17.5 cents, while in very large factories it falls to 12.5 cents. However, there are no definite data in this question, and in certain cases small factories may work more advantageously than the large ones.

However perfect may be the working of the various mechanical devices of a beet-sugar factory, the extraction of sugar from beets can never be a success if these do not contain the sugar; hence the manufacturer and those interested in the success of the enterprise should do all in their power to prevail upon the farmer to devote to his crop of beets the care and time that are necessary for success.

We have been asked to publish side by side data of the cost of working a beet-sugar factory in Germany or France as compared with those now existing in the United States. We decline to grant this request, for it would be doing an injustice to the existing conditions of the American beet-sugar industry. We do not even care to compare one American factory with another. When various technical, etc., problems have been solved there will be time enough to go into several scientific arguments relating to the industrial question taken as a whole. A factory in California may have certain advantages as regards labor that may not be found in Nebraska; on the other hand, fuel and ample water supply may more than compensate for the excessive daily wages of men employed. As matters now stand a just comparison would be impossible, and we are convinced that builders of these several plants are obliged to alter their methods to meet, in a measure, the demands of the local environment in which the factory is to be built. One need only compare the difficulties that were to be overcome in Europe, the early part of the past century, in the extraction of sugar from the beet, with the simplicity of the situation as existing at present, where every individual directly or indirectly connected with the factory has had many years' experience, to

appreciate what great credit is due to American enterprise and money in actually making sugar at a profit during the first campaign, in cases where the several hundred persons employed are doing work of a special kind without any previous experience. A bounty for a few years is needed in every state. We are rather inclined towards a government bounty on export, or a state bounty based upon some sliding scale encouraging the cultivation of superior sugar beets and improvements in processes of beet-sugar manufacture.

**Comparison between cost of manufacturing sugar in France and Germany.**—The future of the sugar industry in France is certainly very uncertain, and the $1.20 duty on 100 kilos of sugar is not sufficient to protect the home sugar manufacturers against the invasion of German sugar. During 1901–1902, the average raw-sugar extraction in France was 11.67 kilos per 100 kilos of beets sliced. The total cost was $8.59 per ton of beets. In this amount the beets represent $5.09, transportation $0.60, cost of manufacture $2.40, interest and sinking fund $0.50. If the resulting pulp and molasses were sold and brought $1.14, $7.45 would be as the actual cost for 116.7 kilos of sugar extracted, or $6.38 per 100 kilos of raw sugar. In Germany the total cost was $7.22, of which the beets represented $4.72, cost of manufacture $2.00, interest and sinking fund $0.50. When allowance is made for the sale of molasses, the cost becomes $6.90 for 136 kilos of sugar, or $5.08 per 100 kilos. The difference in favor of Germany is $6.38 − $5.08 = $1.30. So, as previously stated, at a sacrifice of 10 cents per 100 kilos, or 1 cent per 22 pounds, the sugar of German labor and capital is destined to compete in France with the indigenous product. In all such calculations the data used are necessarily not constant, but are subject to numerous fluctuations. Upon general principles, however, they may be said to be correct. The comparison is sufficient to show our readers upon what an extremely narrow margin the future of an industry may hang, not necessarily through a badly managed administration, but the outcome of special circumstances of cheap labor combined with several recent agricultural difficulties.

**Utilization of beet-sugar factories the entire year.**—The sugar industry utilizes its material only during a few months of the year, and the interest of capital invested has consequently to be realized during a very limited period. This fact contributes in a very important measure to the difficulty of making the enter-

prise profitable. It would certainly be desirable to establish certain industries close at hand which could turn to account the boilers, engines and various machines of the sugar factory after the sugar campaign had ended. The special industry in question should also permit the consumption of a certain amount of the sugar of the factory. Molasses forage combinations are becoming popular and they may be made in the factory proper. These products, consisting of palm-oil meal, with wheat middlings, etc., would yield molasses cakes for feeding purposes under very economical conditions. It is also proposed that the various appliances, such as triple effects, be used in the manufacture of certain essences from aromatic plants. Condensed milk is another industry which has been suggested; the milk evaporated in the triple effects could be combined with sugar in the vacuum pans. In Germany, it was proposed to use the centrifugals of the factory after the sugar campaign had ended for washing of wools and extracting the salts they contain. Central slaughter houses with manufacture of prepared or concentrated beef juice have also been suggested. Soap manufacture could form an annex establishment in which the fat residuums could be utilized. The wastes, such as blood, bones, hair, etc., could be worked up and constitute an excellent fertilizer. Another writer suggests that a brewery with high fermentation might meet the requirement or again a central distillery or starch manufacture. As regards the manufacture of chocolate, artificial honey might also have certain advantages. Very hard wheat in certain countries could be utilized for the manufacture of macaroni, pastes, etc. In those countries where communications are difficult, the motive power of the beet-sugar factories could be utilized to advantage for working the sawmills or for general milling purposes.

Some chemists are discussing the advisability of manufacturing sugar from milk, after the beet-sugar campaign has terminated. The idea is a practical one where dairying establishments are near at hand. The milk could be heated 75 to 85° C., then combined with 5 to 9 per cent lime at 20° B.; defecation with carbonic acid and the scum filtration and other like operations could be continued with the existing sugar arrangements. Concentration and evaporation of the clear liquor to 17–20° B. is then followed by granulation. It is estimated that 3 per cent sugar could be obtained, and that the profits would be over one-half cent per quart of the milk worked.

The starting of the accessory industries would have the advantage of collecting around the factory a stable population, and women and children could thus find numerous occupations. Besides the interest connected with a better utilization of invested capital of the sugar manufacturer, the combined industries would tend to limit the inclination of the rural populations to move towards the cities by bringing about a closer connection than hitherto between manufacturing and farming interests of the country, one of the essential conditions of a nation's prosperity. From our point of view, while admitting all these theoretical advantages, there is a practical side that must not be overlooked and that is the danger of certain ferments remaining after the annex industry has ceased working. This would tend to bring about an inversion of the sugar made. Under the best possible conditions great advantages are found in submitting all the machinery to a thorough cleaning after a sugar campaign. Every pipe, etc., is taken apart and various apparatus unmounted; the calcic and other deposits are removed and there follows a better efficiency in the working of the machinery during the three months that the sugar factory is working. The gain realized would in a large measure compensate for the advantages in having the plant work for, say, ten months in the year. Experience furthermore shows that in the various processes of sugar extraction numerous improvements are being made and the narrow margin of the manufacturer's profits demands that his plant keep pace with the progress of the times.

# EXPLANATIONS RELATING TO THE ABBREVIATIONS USED IN THIS VOLUME.

The first name is that of the author, the second the title of the book consulted; the broad-faced numbers refer to the volume, the figures that follow give the page or pages, and the last number refers to the date of publication. The Roman figures relate to edition.

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# BEET-SUGAR MANUFACTURE.

## PART I.

### *PRELIMINARIES.*

## CHAPTER I.

### DELIVERY, UNLADING AND TARE ESTIMATION.

**Delivery.**—The date of the beginning of the campaign does not depend entirely upon the maturity of the beet, but also upon its saccharine quality and the daily working capacity of the plant. If a factory must handle a large tonnage of beets and the campaign is to last for a considerable period, it is important that the slicing begin as soon as possible. In Europe this means usually from the first to the middle of September; but not before the laboratory analyses show that the extraction may be conducted on a paying basis. To obtain the requisite data to correctly decide this question, it is important that analyses be made of numerous beets taken from the field at least two weeks or a month prior to the proposed date for opening the campaign.

If the factory can rely upon only a very small crop it is desirable that the slicing be postponed as long as possible, so that only mature beets will be handled from the start, and that the roots used be fresh from the field without any necessity of special siloing. It is evident that the first essential for the manufacturer to consider is how he can obtain the maximum sugar extraction from the raw material to be handled. Beginning too soon means the handling of semi-matured beets; commencing too late means

that the roots must be siloed throughout a long period of months during which certain saccharine losses will surely occur.

It is desirable that the beets furnished to the factory be drawn from farms within a reasonable radius, so that too much time and money will not be involved in transportation. The whole question of delivering beets during the winter months offers greater difficulties in this country than in Europe, owing to the bad condition of the roads in many of the states. In California, under the special conditions existing, it is possible to carry beets by rail as far as 100 miles, thus permitting the farmers of one locality to compete with those of another, which results in making the manufacturer so much the more independent.

**Organization.**—An important factor in the success of a factory is the regularity with which the beets are delivered, and, therefore, some factories adopt the plan of informing the farmers of the number of tons they need per diem and per week. But all factories are not in a position to make such demands, which frequently do not coincide with the previous arrangements of the tiller. The fact is the European farmer in most cases delivers the beets when he sees fit, regardless of whether they may be needed just at that moment or not. Hence in all well-organized beet-sugar factories special provisions are made to meet every possible emergency that may present itself in this connection.

**Reception.**—Beets may be delivered by land, by water or by rail. The arrival and departure of the carts, wagons and barges should be effected in good order without any possibility of delay or disputes and to this end attention should be given to the receipt of the beets, so as to prevent collision of the vehicles. Upon general principles orders should be given that the wagons after unloading make a circle around the factory. With carts this practice is almost indispensable if the unloading is to be conducted systematically. In detail the systems of controlling the cart delivery of beets differ considerably at different factories. The conditions are, of course, not the same when delivery by barges is in question.

The determination of the weight of beets carried by cars is simplified by the fact that a single weighing is sufficient. The ascertained weight is marked on the side of the car, and as it has, therefore, only to be passed once on the weighing machine it is easy to avoid any block on the rails, especially if the track makes a circle around the factory. In every case when tracks

are laid, if the premises will permit it, the use of turntables should be avoided and sidings employed to allow of easy shifting.

The machines for weighing the wagons filled with beets are simply modified "Roman scales," such as are used in weighing carts. However, the weighing machines in which the rails are independent of the table of the machine are specially recommended. In weighing a car the stand of the machine is lifted until it comes into contact with the interior flange of the wheels and the wagon is raised. The weight is taken and after the operation the table is lowered and the wheels again rest on the rails. The wagon is then pushed off the weighing machine and shunted without difficulty, and, as it does not come in contact with any of the mechanism, cannot be injured. In the mode of double weighing, the weight is first taken with cars or wagons full of beets and again when empty, the difference giving the weight of the roots. The dirt, etc., is supposed to fall to the bottom.

**Car shifting.**—The mechanical means used for shifting the cars depends upon the number to be handled. In large beet-sugar factories, such as the 500-ton slicing plant, locomotives are preferred, and for such purposes one of the diminutive locomotives so generally in vogue is quite adequate. WAGNER * gives the preference to machines worked by accumulators for shunting single cars. These are loaded with 5000 kilos of beets and turn on a radius of 12.5 meters. The cars may be taken off the rails and drawn by horses, in which case special wheels are used, and the wagon thus formed may be brought to the middle of the fields where the beets are growing. These electrical locomotives are furnished with accumulators of 100 HP. each, which will haul six wagons loaded with from 5000 to 10,000 kilos of beets. The accumulators may be charged by means of a trolley while running, but can also be operated without a conducting wire.

Unless the traffic is excessive, or the distance from the depot to the factory too great, small locomotives of the DECAUVILLE type, constructed for narrow-gauge railways, are sufficient for the work. The tracks may be placed between those already laid, or, as is generally done, a third rail may be used in combination with the standard rail, so as to form a narrow gauge upon which the diminutive locomotive may run. Under some conditions, electric locomotives on narrow-gauge tracks, using an overhead wire, give satis-

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* Z., 49, 1010, 1899.

factory results. The use of electricity in accumulators has not always given the practical results expected owing to the limited power at one's disposal. An engine with accumulators, for example, hauls from 30 to 50 tons and cannot be used on grades, but it may be applied to the DECAUVILLE trains.

When beets are loaded on barges in heaps, they should first be weighed, on account of the labor necessary for their removal. If this precaution has been taken the roots may be emptied directly into the hydraulic carrier when brought to shore from the boats in baskets, if the factory be sufficiently near at hand to permit of this combination. A weigher's certificate should always accompany each load.

**Wire-rope conveying.**—When distances to be covered have varying elevations the PROVIN idea may be adopted. This mode is as follows:*

"A rope is fixed at both ends. The baskets move by gravity on a slant of 21 mm. per meter. The rope is supported in the air by an ingenious apparatus. Evidently if some precautionary measures were not taken, it would be likely to break in consequence of repeated shocks received at the point of intersection of the rope and the support at the passage of each basket. To avoid this there is affixed to a projecting arm a weight which gives way at the dangerous moment and returns afterwards to its normal position. The empty baskets return by a second rope, which has a smaller diameter, having less to support. The slant of this rope is the opposite of that of the first-mentioned cable. The first cost for this combination for distant overhead transportation is said to be about $900 a mile. Evidently this amount increases inversely with the distance; that is to say, if the first mile cost $900 the second would cost much less.

"This system can be worked by two men and a boy, but with a greater number of hands as many as 100,000 kg. can be sent to the factory daily. This idea is considered most excellent, but for short distances only."

**Flumes.**—More economic than these methods of transportation is the hydraulic carrier for beets, consisting of flumes or sluices, which are described in considerable detail under another caption. These flumes may be iron or cemented gutters, slightly inclined, in which a current of water circulates in sufficient volume to float the beets to the factory. The beets are brought from the boats by hand.

* WARE, The Sugar Beet.

**Forks or hands?**—At many factories beets are unloaded with pitchforks having four, five or six prongs. The prongs are liable to break off, owing to the resistance offered by the mass, but WOHANKA overcomes this difficulty by using movable prongs, which are protected by wooden balls that prevent the roots from being injured. Experience shows that all bruises, however small, diminish the keeping qualities of the beets in the silos and render them more liable to the infection of objectionable germs which may exist in the adhering earth than are normal beets. It must also be remembered that pieces of beets give inferior cossettes in the slicer. In spite of all these considerations beets are mutilated by the general use of forks, and therefore many European beet-sugar factories prefer to unload the beets in a most primitive fashion by hand. As each root passes through the hands of boys and women, to whom this task is left, the beets are to a certain extent cleaned of the adhering earth, which is naturally not removed by the forks, and stones also are usually left behind. This system of unloading is more economical in Europe than one would imagine, especially when the hands are paid by the task.

**Unloading carts.**—Generally carts are emptied by the persons delivering the roots. On the other hand, cars of beets are unloaded by the laborers of the factory either by hand, as explained above, or by forks. To facilitate the unloading it is recommended that the space at the side of the cars into which the roots are to be thrown be defined by a small wall or fence as high as the bottom of the car, so that the beets need only be pushed out either in heaps or into the silos. When the heap of beets reaches a certain height this arrangement loses its utility, and for this reason the track and the silos should always be at a different level, so that the greater portion of the beets delivered may be unloaded with ease and at little expense. This method of unloading is now employed at many factories in Germany and is worthy of adoption.

A spot where the unloading can be done readily and at the smallest possible cost should always be selected in advance. However, as the unloading of beets arriving in boats always costs more, whether they be disposed in heaps or delivered into the beet sheds, than when they are delivered by cars, those received by the former method are sliced immediately and thrown at once into the hydraulic carrier.

**Unloading barges.**—The mode of unloading beets from barges differs considerably from factory to factory. If the sugar plant

is located at some distance from the water, very crude methods must frequently be adopted for the unloading of the beets. Occasionally the roots are thrown into wheelbarrows and dumped in heaps in the yard of the factory or near the flumes, if these exist. When the barges draw considerable water it is necessary to unload them with baskets, lifted by means of a windlass, and subsequently emptied into wheelbarrows. Cranes are also used to lower a receptacle into the barge. The frame of a DECAUVILLE car may answer this purpose, and when filled it is raised and replaced upon the truck from which it was taken. When there is a flume small wicker baskets holding from 25 to 30 kilos are raised to the proper height and emptied into the feeding trough. To prevent the beets from falling into the river or canal an inclined plank leads from the hopper to the interior of the boat. In case the barges are more than 2 meters deep it is necessary to fill the large wicker baskets containing at least 125 to 150 kilos and to raise them by means of a crane. Care should be taken, however, not to empty such a large quantity of beets too suddenly into the hopper connecting with the flumes, as this would cause an obstruction in the hydraulic carrier and result in irregular delivery at the other end. This method of unloading is actually in use in nearly all the sugar factories where the peculiar location of the plant does not offer an insurmountable obstacle.

Different methods have been tried to make the unloading of the boats entirely mechanical by employing elevators, such as are used for grain. These attempts have met with no success, but some factories have used beet elevators run by electricity, and the same appliance is used for shipping and unloading beets. DENIS has constructed a series of spirals placed on supports, which aids in overcoming certain obstacles. During the last few years numerous experiments have been made in France and Germany for the mechanical unloading of railway cars by means of special apparatus. The results obtained seem to be satisfactory; but these methods are used very little at present.

**Net unloading.**—A method of unloading beets into a railroad freight car is interestingly described by MYRICK,* the arrangement of which is shown in Fig. 1:

" A strong net is placed on the bottom of the wagon or cart, the ends of the net lopping over the two sides. The beets when

* The Sugar Industry.

dug are thrown by hand into the wagon, which is then driven to the freight car. Here the net on the side next the car is attached to the car at (*b*). The two ends of the net and its further side are fastened together and made fast at (*a*). Here a chain is attached leading over the car to where a team of horses is hitched to a whiffletree. The team starts up and thus dumps the whole wagon

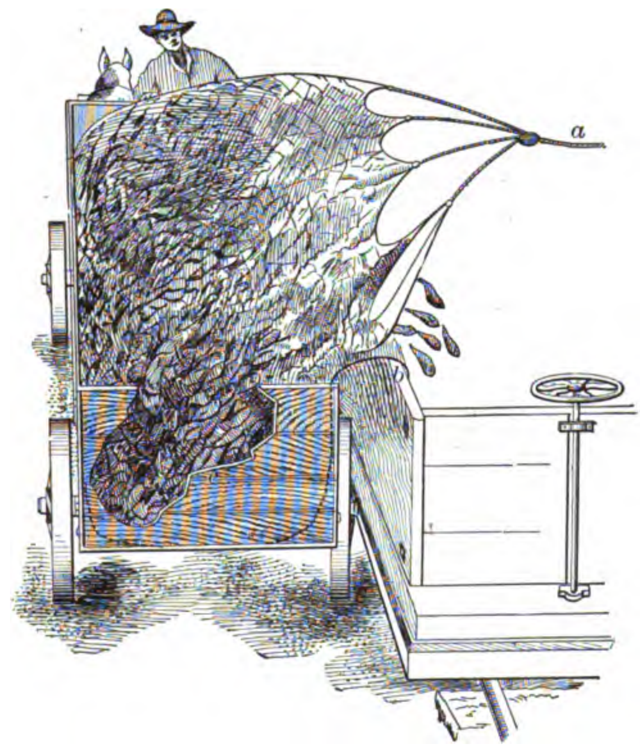


Fig. 1.—Net Unloading.

load of beets into the car. The whole job takes but a few minutes and saves all hands work. Indeed the beets are not touched by hand or by hand tools after being thrown into the wagon from the field where they grew."

An appliance of this kind is certainly destined to render great service. We previously pointed out "that the manufacturer in most cases has no more consideration for beets than he has for lime, coal or any other raw material, forgetting that roots are living organisms; even after they have been harvested, they should

be handled with great care up to the moment they enter the slicer. Sugar beets even in silos breathe more rapidly after a bruise and thus consume the nutritive substances faster." *

The mode of obtaining a sample of beets adopted at the Los Alamitos, Cal., beet-sugar factory consists in placing a basket near the centre line of the car about to be unloaded, and as soon as the car is slanted at the desired angle, so that the roots will fall into the beet shed beneath, the basket is filled. The beets so obtained certainly represent a reliable sample for tare estimation.

**Dumping carts.**—Beet dumps have assumed a more practical shape in most American beet-sugar factories than in Continental Europe, the improvements having been made mainly in California. The principal objection to the previous mode was its excessive slowness. The CARROLL dump was introduced and met with considerable success from the start. By this method five tons can be emptied from a cart into a railway car in one minute and the cars are rapidly filled. The inventor says: "To empty a wagon load by means of this dump, the wagon or car is first run up the dump. In case of a wagon the team is not unhitched but remains standing on a solid platform during the operation. When the vehicle is upon the dump an attendant will hook a rope or chain, which hangs above the platform for the purpose, to a catch which holds the side of the vehicle bed in place; then another attendant on the other side of the vehicle will throw a lever, which brings a support against the hubs of the wheels; yet another lever is thrown, thus tipping the dump platform and the vehicle sidewise."

If the quantity of beets to be unloaded is not sufficient to justify the expense of such a device a portable dump is used, which is mounted on car trucks and can be drawn along the tracks from station to station and placed on the side track until the beets of the locality are loaded. The Anaheim Beet Growers' Association declared that by the dump that had hitherto been used only 200 tons could be loaded in a day. By the new device 600 tons per diem is an average. It was reported that on one day there were loaded seven railroad cars, of twenty tons each, in a little less than one hour and three-quarters.

**Dumping cars.**—In ROISIN's system, which is in use at the Nassandre sugar factory in France, the cars are pushed onto a movable

* S. B., Aug. 1900.

platform operated by hydraulic power. The back of the cart is opened, a sample taken for the tare, and the cart is raised to an angle of 45° above a ditch, which is sufficient to allow the beets to fall out. The platform then falls back to its original position. The whole operation does not last more than a few seconds. The ditch may contain from 18 to 20 tons of beets. The sides of the ditch are of sheet iron placed at a considerable angle, and the lower part is furnished with registers of a rather peculiar form, worked by hydraulic power, which allow the beets to fall into small cars of the DECAUVILLE system. These cars are drawn from under the ditch by wire cables operated by electricity and are subsequently raised to 3 meters above the level of the silos, when the slight incline of the track allows them to continue their route to the place where they are to be unloaded. Eight cars of 500 kilos capacity each suffice to unload 400,000 to 500,000 kilos of beets per day. The motive power is estimated at 2 HP. to upset the cars and 4 HP. for the cable which does the hauling.

Railway cars can be unloaded in the same manner. A similar installation has been used in Germany and works perfectly. It is desirable that the place of unloading be covered so as to prevent the animals and the men from taking cold in the yard. During the unloading the beets which are last delivered may be used at once to make room for others coming in. Manual labor is thus saved. In dry weather there is a decided advantage in making a reserve stock of beets arriving by carts, the heaps being made as delivered. The beets from barges should always be the last to be unloaded on the piles on account of the great amount of labor involved.

**Necessity of siloing.**—Beet-sugar factories are not always arranged so that they may at once utilize all the beets received. With the exception of the beets delivered by barge and unloaded directly into the hydraulic carrier, the roots are generally kept some time, depending upon the daily consumption at the factory and the regularity and rapidity of delivery. The ideal method would certainly be to so regulate the arrival of the beets that they could be sliced at once, but these conditions are never realized. It is necessary, therefore, to have a certain reserve, by means of which the irregularity of deliveries may be corrected. If a comparatively regular delivery could be assured until the end of the campaign a very small reserve would cover the emergency. Certain factories make a provision for hardly more than one night's work, but as a general rule this is a mistake, as 36 hours' slicing is the lowest reasonable

limit. This reserve stock is generally kept under sheds. If rapidly delivered the beets are unloaded in heaps on areas reserved for the purpose, and the usual precautions for their satisfactory keeping should be taken.

**Covered sheds.**—In most factories the flumes of the hydraulic carriers are in the open air, especially for the beets that are to be sliced without delay, and there can be no objection to this arrangement. However, in many cases covered sheds are used, and this mode has many advantages, especially when the hydraulic carrier is worked during rainy weather, or when there is a general stoppage of the plant. These covered storehouses are often provided with sheds extending their whole length to shelter the horses and carts and the workmen who attend to the unloading. The sheds may be built very economically by simply covering the ditches or banks where the gutters run with felt roofing. As the reserve stock is accumulated board partitions may be put in between which the beets can be stored to a considerable height. The beams of the roof run the entire length of the ditches and are held by two struts so placed as to leave sufficient space between them to move the board partitions.

Suitable sheds or covered silos holding thousands of tons are constructed to meet the requirements of each special case. In most European factories the reception sheds need be of only a limited capacity, as the roads are excellent and allow delivery during the entire campaign; but such is not the case in America, where the sheds are enormous and have a capacity nearly sufficient for the entire slicing period. Large beet sheds have certain very objectionable features, especially when the roots are piled up over the hot-water canals used for transportation. When thus exposed to this semi-moist vapor, the beets become softened, are difficult to handle in the slicer, and yield juices that are not only dark in color but show an important decrease in sugar percentage compared with the extraction from roots brought fresh from the field.

**Beet cellars.**—The sheds, silos, etc., for beets may be arranged either above or beneath the surface of the soil. When underground they become in the true sense of the word beet cellars. Cellars for beets are most rational and are decidedly advantageous in that their filling and emptying from the lower canal can be accomplished at a comparatively slight cost and with a gain in time. In the small cellars used in Europe the roof covering has for its principal object the protection of the animals and men, as the roots do not

specially need this protection, except in countries where snow is to be feared.

A beet cellar is simply a ditch the bottom of which is formed by two inclined planes slanting toward the carrier. These cellars are, however, objectionable in that they join the flumes at a depth considerably below the washers, and as a result the beets have to be subsequently raised.

A beet cellar can be advantageously arranged on the side of a hill when one is situated near the factory. Under these conditions a cellar may be dug sufficiently deep without the necessity of removing the dirty water from the washer and without danger of stagnant water.

If beets are delivered in railway cars the sides of the cellars should not be higher than the level of the floor of the cars, so as not to interfere with such bottom-emptying devices as may be employed. Arrangements that allow the tracks to pass directly over the cellar give satisfaction. The width of these cellars should be calculated so that the slant given to their sides will allow the beets to fall or slide naturally into the bottom flume. If this detail is neglected considerable work will be needed to force the roots down when the canal is uncovered, which involves a considerable increase in the cost of labor.

**Tare.**—This operation of calculating the tare, or making allowance for the dirt and impurities adhering to the beets, is of the first importance when the beets are delivered in the yards of the factory. Sometimes the tare is simply estimated, but in most cases it is found preferable to make a direct determination, under which circumstances special stress should be placed upon the selection of the samples.

Although at some factories it may be very difficult to obtain accurate results if there are a large number of farmers making small deliveries, it is advisable to take a sample of the beets as they arrive in the carts and determine the tare without delay. Tare estimation upon samples of beets is very inaccurate. In comparing two cart loads of beets which had been thoroughly washed and all foreign substances weighed, it was found that the tare in one case was 16.8 per cent and in the other 24.6 per cent, and comparing these practical results with laboratory washing we find that the sample taken from cart No. 1 gave a tare allowance of 12.2 per cent instead of 16.8 per cent, and that from cart No. 2, 18.14 per cent instead of 24.6 per cent.

**Sampling.**—The tare of the adhering earth is determined in the same manner for all beets, whether they arrive by trucks, barges or carts, with this difference, that from trucks of 10,000 kilos two samples of beets are taken at different periods of the unloading and from barges a still larger number. For small loads experience shows that there are advantages in taking a sample anywhere from the mass at the beginning towards the end of the unloading, or even during the operation. It must not be forgotten that at the bottom of the carts the beets are dirtier than they are on top, as the earth falls down through the mass.

It is always preferable to take the sample with a pitchfork rather than by hand, for notwithstanding the intention to be impartial, there is always a tendency to select the cleanest and the smallest beet. Furthermore, the fork will pick up not only the beet, but also the tip ends, broken bits, etc., that hand selection would naturally leave to one side. In most European beet-sugar factories the sample for the tare is 25 kilos, but in cases where hand selections are made the sample should include from 80 to 100 beets.

**Cleaning.**—The operation of estimating tare consists of weighing the dirty beets, thoroughly washing them and weighing again. The baskets in which the beets are placed should be, as far as possible, of exactly the same weight, and, furthermore, should be kept scrupulously clean, so as to simplify the operations. At certain factories the beets are not washed but are scraped and brushed to remove the adhering earth. During washing the beets absorb a certain quantity of water, increasing the weight so that one seems to find less adhering earth than in reality existed. According to PELLET,* beets may actually absorb during the washing 0.1 to 0.3 per cent of water. The increase of weight of the *strained* beets is from 0.8 to 0.9 per cent, this difference being due to the water adhering to the surface. As a general thing an allowance of 1 to 2 per cent is made for this circumstance.

**Washing.**—For the tare determination small hand washers are used. Those of the LEHNARTZ † model, for example, consist of a trough in which a drum revolves, on whose outer surface is a series of slats sufficiently near together to prevent the beets from escaping into the interior, but yet allowing the dirt, etc., to settle at the bottom of the trough. The axis of the drum is held by

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* B. As., **15**, 198, 1897–98. † N. Z., **13**, 213.

two rods that turn when necessary on one side of the trough, so that the drum may be removed and emptied.

Other types of laboratory washers permit the beets to be removed from the drum by simply reversing its motion. In the interior is a series of projecting arms arranged around the axis in a spiral, thereby forcing the roots to make their exit when the direction of the movement is changed. There are several hand washers of this kind that may be worked mechanically by simple belt communication with a pulley.

**Dressing.**—In some factories the tip ends and the small adhering roots are removed in determining the tare. This mode is not in general practice, for it is in most cases followed by abuses and disputes. The green necks or tops of the beets or the portions above ground should be removed and left upon the fields where the beets were grown. The farmer has everything to gain by this method, as the tops contain most of the plant foods absorbed by the beets during their development, and these elements are thus returned to the soil. Furthermore, as the tops contain a comparatively small sugar percentage they would necessarily reduce the average, when the roots are paid for in proportion to their sugar content. Not many years since it was maintained that topped beets lost more sugar during siloing than whole beets, but HANAMANN's * experiments appear to demonstrate that this is not the case. On the contrary, it appears that topped beets offer decided advantages, as with whole roots there is always danger of second growth, with corresponding sugar loss, which is much less to be dreaded when the crown is removed. Beets that are harvested during rainy weather should be sliced at once.

COURTOY † proposes to offer special prizes to farmers for the delivery of clean beets, while some urge that special fines be imposed on tillers who deliver very dirty beets, the conditions to be fully detailed in the contract between the farmer and the manufacturer. Every effort should be made to convince the farmer that beets with adhering earth are in the end more expensive to haul than those reasonably cleaned after harvesting. It is too frequently overlooked that the soil in question contains plant food valuable to the tiller, and if it is removed from the field where the beets were cultivated the loss must be made up by the use of fertilizers.

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* Z., **35**, 695, 1885. † La. S. B., **23**, 435, 1894–95.

The weight of the tops is also determined after they are cut from the roots.

**Discussions.**—As the sample does not represent more than 0.25 per cent of the total capacity of the wagon or railway car the estimation of tare is not as exact as it should be and results in numerous discussions and frequently legal proceedings between the partie. interested. In order to prevent any possible discussion between the farmers and those receiving the beets, it is customary in certain parts of Germany to post placards calling attention to the fact that those interested may witness all operations appertaining to tare determination, and that those who do not avail themselves of this privilege shall have no right to complain after the work has been accomplished. Another excellent custom consists of printing notices which give full details of the mode adopted for tare estimation, these notices forming part of the actual contract. Sometimes there is an excessive amount of earth adhering to the beets and serious complications follow during the hydraulic transportation and the cleaning in the washer. It must not be forgotten, furthermore, that such beets are difficult to keep in a satisfactory condition in the silos. In such cases it is frequently necessary to deduct 50 per cent of the total weight of the beets delivered. The farmer naturally objects to this, and the better plan is to refuse the entire lot, or to dump them into a pile so that an examination may be made and their removal permitted if they should be ultimately refused.

**Change during transportation.**—Too little account is taken of the evaporation of the water contained in beets during the interval that elapses between harvesting and delivery at the factory. The evaporation is to the farmer's advantage, but means an important loss to the manufacturer, for when beets are purchased on a basis of their sugar content, they will contain a relatively higher percentage after a certain amount of water has been evaporated than before. The reverse is true when purchased by weight. Experiments show that when beets are exposed to the sun for a week they may lose 35 per cent of their weight.

Without doubt the greatest enemy of the beet during transportation is frost. If the beets upon reaching their destination are frozen in a compact mass their unloading is almost impossible Precautions should be taken to work up the frozen beets at once, as they will rot if left for a period of days or if exposed to the hot vapors of the shed and thus gradually thawed. On the other hand

if they can be kept frozen there is no objection to their siloing and subsequent slicing in that condition. In cases where beets are brought to the factory in boats by canal or river, it is most important that the conveyors in question be flat-bottomed and not covered, and that the roots remain in them the shortest possible time, as otherwise they are soon heated and become soft, which, as previously explained, results in dark-colored juices.

To prevent the decomposition of beets during their transportation in barges, SIMON* places the roots on slats and forces sulphurous acid through the mass, circulation being obtained by means of vertical flues. This mode cannot be recommended, as it is impossible for men to work in such an atmosphere. Antiseptics give far better results.

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* S. I., 44, 71, 1894.

## CHAPTER II.

### SILOING AND CHANGES DURING KEEPING.

**Conservation of beets.**—The volume of beets to be siloed depends upon the organization of the delivery; as each sugar factory has a maximum limit for its daily slicing, all roots landed in the yards in excess of this capacity must be stored.

Harvesting should not begin until the beets are entirely matured, for if the roots are developing they have a stronger hold on the soil and the danger of bruising is very much greater than when that part of their growth is completed. Maturity is evidenced by the falling of the old leaves. Just before this period the organic substances are stored in the necks and there is then an interval of rest, during which slicing should take place as rapidly as possible. Beets should be siloed so that the fresh air received by ventilation is the same as that secured by the roots in the soil.

Judgment must be used to determine which beets should be siloed. Among the factors to be considered are the cost of siloing and the degree of cleanliness of the roots. For immediate working preference should always be given to dirty beets. Those that are delivered in the smaller carts and those without earth adhering to their surface should be siloed.

**Changes during keeping.**—The loss of sugar during the keeping of beets is due to various causes, among which are the vital changes of the plant proper. These may be mainly attributed to second growth or to fermentation, and the latter may have been caused directly or indirectly by excessive heat or cold and the want of proper ventilation. Freezing and subsequent rotting are also much to be dreaded. Some of the leading authorities differ as to their causes and the subsequent transformations; for example, SCHEIBLER* discusses the disassimilation that is produced, claiming that it is followed by the destruction of small quantities of the asparagin of the beet. PAGNOUL† pointed out some years ago that there is

* Z., **16**, 228, 1866, and **20**, 20, 1870.

† S. I., **38**, 246, 1891.

formed a certain amount of ethyl alcohol; and the investigations of MAREK * apparently prove that the richest beets lose the greatest amount of sugar. This assertion is very much in contradiction to previous observations and to the opinions of the leading authorities of some twenty years ago. One fact appears to be certain—that the fertilizers used during the cultivation of the beet have an important influence on the change during siloing. The plant foods that tend to prevent sugar formation will also diminish the keeping powers of the roots. Even the mode of using the phosphoric fertilizers has an influence. These facts speak for themselves and show how important it is for the manufacturer to give the agricultural problems his closest attention. As PROSKOWETZ declares, the keeping power of beets without doubt depends largely upon the individual characteristics of each variety; but whether there can be created a type that would undergo little or no change during keeping has not yet been determined. STROHMER † also agrees with the assertion that the individual characteristics of the beet play an important rôle as regards the sugar consumption which does not depend upon the saccharine quality of the beet. The volume of air placed at the disposal of the beet has also an enormous influence regarding the changes that occur during siloing. On this question the authorities do not agree; for example, HERZFELD points out that the volume of air allowed to circulate in a silo should be limited to the minimum needed for the respiration of the plant. Remove the air entirely and the sugar transformations still continue. According to STROHMER, under these circumstances, instead of its being the oxygen that burns the sugar, the roots, between 2° and 4° C., resort to an intramolecular breathing; that is to say, carbonic acid is formed by taking the fuel and oxygen through a sort of combustion of the tissue itself. Under these circumstances there is formed a small quantity of ethylic alcohol, as has been previously pointed out. Even after 72 hours, beets that have been deprived of oxygen still continue to breathe; however, the roots must certainly have a certain amount of oxygen to maintain life. The carbonic acid should be removed through ventilation. For every kilogram of beets siloed at 5° C., 4 to 7 mg. of sugar per hour are consumed.

**Influence of sprouts.**—As regards second growth it is important to note that the sprouts under favorable conditions may attain a con-

* Z., **39**, 932, 1889. † Oe.-U. Z. **31**, 933, 1902.

siderable length, especially when the temperature is comparatively high. One of the main reasons for their development is carelessness in the operation of topping. Beets should always be topped below the cycle of green leaves, thus removing all the bud eyes. STROHMER points out that at high temperatures, owing to their second growth, beets that have not been topped will lose more sugar than topped roots. This entire question, however, is open to controversy. CORENWINDER * discovered in these shoots the presence of small quantities of invert sugar and saccharose, which evidently came from the root proper. The quantity of sugar which passes from the roots to the leaves can never be very great, as second growths taken collectively never represent more than 2 to 3 per cent of the weight of the root from which they were formed. These sprouts contain as a maximum 3 to 4 per cent of reducing sugars, which in reality is a maximum and not an average. According to CLAASSEN † one must look to other causes than excessive sprouting for an explanation of sugar losses during siloing. Experiments appear to demonstrate that under like conditions of temperature and in complete obscurity, beets with sprouts throw out very little more carbonic acid than normal beets. On the other hand, STROHMER insists that a certain percentage of the sugar in the beet is inverted when the sprouts form, forming mainly pentose. These losses added one to the other—sugar in the sprouts, slight increase in the breathing and the change of sugar into non-sugar—are factors that cannot be overlooked. The result is that after these alterations the final juice obtained is less pure and necessarily offers greater difficulty in sugar extraction. It seems reasonable to admit that an analysis of the sprouts would give a general idea of the changes that have taken place.

When beets develop a second growth during their keeping it indicates that the environment is too hot and moist. The formation of these sprouts indicates a special vital activity that necessarily means greater respiration and consequently a corresponding amount of sugar consumption. However, properly speaking, there is during the second growth a comparatively small loss of sugar, as the increase compared with the total weight of the beet is very slight. The temperature in the interior of a pile or of a silo filled with beets depends upon its height and the ambient temperature.

**Retarding the second growth.**—At one time it was thought

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* Z., **27**, 21, 1877. † Z., **42**, 382, 1892.

that the sugar losses due to second growth could be overcome by forcing sulphurous acid through the mass of roots, as the sprouting would then cease.

**Examining a silo.**—When a silo was suspected of being in bad condition, it has been the custom to open its centre, and if the roots there were found to be satisfactory the mass taken as a whole was considered to be in a normal state of preservation. This mode is faulty and the portions in contact with the straw covering should be first examined. Straw has many objectionable features, although in certain cases it renders important service.

**Watering beets.**—Some years since it was customary in France to sprinkle beets in silos with a reasonable amount of water, the object being to replace the water of evaporation. It was maintained, and there was ample authority to show that there was reason for the assertion that wilted beets ferment more readily than normal ones.

**Extent of losses during siloing.**—The modes of storage have an important influence on the extent of the sugar losses during siloing, as is shown by the following:

SUGAR LOSSES IN DIFFERENT MODES OF STORAGE.

| | CLAASSEN. | LACHAUX. | ESCAUDŒUVRES. Sugar Factory. |
|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. |
| Large piles not covered | 0.010 to 0.012 | | |
| " " well ventilated | 0.012 to 0.017 | | |
| " silos covered with earth | 0.019 | | |
| Silos covered with earth not ventilated | ..... | 0.029 | |
| Silos covered with earth well ventilated | ..... | 0.019 | |
| Large piles exposed to the air part of the time | ..... | ..... | 0.044 |
| Large piles protected under sheds | ..... | ..... | 0.002 |

The purity of the juice necessarily undergoes considerable change during siloing, as has been mentioned. BRIEM says that while the purity in October was 80.1, it fell to 68.5 in May, became 79.1 in November, 77 in December, 76.3 in January, 75.9 in February, 75.5 in March, and 73.5 in April. There cannot be the slightest doubt that the lower the temperature is during the storage of the beets the fewer will be the organic changes, and

as may be imagined the action of cold is important. Beets freeze at a temperature of $-1$ to $-1.1°$ C. The whole question of excessive cold has an exceptional importance for the United States, and is an issue that has been too frequently neglected. Frozen beets do not differ in their exterior appearance from normal beets, but are slightly browner in color and extremely brittle. When rapidly thawed the color becomes dark and glossy, the tissue is soft to the touch and appears to be entirely changed from its original condition.

Frozen beets have excellent keeping powers, and as long as they remain in that condition may be sliced with little difficulty; but all this changes when the roots are thawed, on account of the non-resistance offered to the blades of the slicer by their soft, flabby state. Furthermore, if they are left in the silo in that condition they will soon contaminate the entire mass, the micro-organisms will have full action and the beets will soon be in a state of decomposition, frequently meaning considerable money loss to the manufacturer. It is only within recent years that any explanation could be given of the real disorganization of the tissues during freezing. The experiments of STROHMER have thrown much light upon the question. He says that no ice is found in the interior of the plant cells of frozen beets. The icicle appears to confine itself to the intercellular spaces; the cells proper are not broken. It is only when submitted to a sudden cold of $-10°$ C. that crystals are formed in the interior of the cells. The reason why the cells die in frozen beets is that their organized protoplasm loses its water. On the other hand, if the frost has not removed considerable water from the protoplasm the cells still retain a certain amount of vigor, and they may be restored to their former activity by resorting to a system of very gradual thawing.

**The rotting of beets.**—Under the influence of a high temperature in the interior of silos, a phenomenon of fermentation may be induced which is frequently sufficient to bring about actual changes in the composition of the beet. Many years ago PASTEUR called attention to the fact that carbonic acid favored fermentation, and urged that the silos be well ventilated so as to eliminate the gas that was the natural outcome of the beets' breathing. The soil upon which the silo is constructed appears also to have an important influence, and KNAUER,* discussing this subject,

* Z., 6, 89, 1856.

declares that beets should not be stored on the same spot during two successive years, for, do what one may, if there remains the smallest germ from which the fermentation may originate, it will soon make its influence felt the following year, the tip ends of the roots and the lateral shoots being the first to rot. Every exposed beet cell means a possible centre for the micro-organism to develop, and herein lies the importance of not bruising beets that are to be siloed. Even the topping of beets always means a wound, and upon the cut there is formed a hard surface by certain bacteria which have been deposited, in which case the sugar losses are considerable. Some forty years ago SACHT * pointed out that the rotting of beets in the silo was due to some exterior cause and not to the root proper. The first manifestation of rot is the cloudy aspect of the juice in the beet cells. From the very commencement the mushroom growth is visible in these cells and increases rapidly. The juice of beets when they begin to rot is neutral, but it soon becomes excessively acid, and herein lies another argument for the importance of siloing beets that have not been mutilated. Some authorities attempt to explain why certain beets tend to rot more than others during the period of keeping. For example, GROUVER † noticed that beets cultivated in nearly exhausted soils would rot even after three or four weeks' keeping, whatever care may have been taken as to silo construction, ventilation, drainage, etc., while, on the other hand, beets harvested from soils where this special crop had been grown for the first time underwent little or no change. In this connection it should be noted that excessive nitric fertilizers ‡ have an important influence. This assertion has been contradicted by HELLRIEGEL,§ for his experiments prove that if these nitric plant foods are absorbed more or less by the beet they can in no way help the development of micro-organisms. It is admitted, however, that when nitric fertilizers are used alone, the resulting beets are more difficult to keep than when considerable phosphoric acid is added, but the reverse is true if this is increased. Sugar losses that are noticeable during siloing are not the only ones that occur, but they are the most important. In keeping beets for several weeks or months an evaporation of

* Z., **12**, 474, 1862.

† Dr. FÜHLING, Der praktische Rübenbauer, edition 1863, p. 213.

‡ Z., **12**, 58, 1862.

§ Z., **36**, 511, 1886.

water takes place which amounts to an ultimate loss of weight, but exposure to the wet may cause a gain in weight.

The rise of temperature in silos should be prevented by every possible means at one's disposal, for while beets that have been abnormally heated show little or no exterior signs of it they are most difficult to work during carbonatation. HORSIN-DÉON declares that juices from such beets do not blacken when exposed to the air, and this is always an indication that something unusual has occurred during siloing. The danger of rise in temperature is proportionate to the mass of beets being kept, and inversely proportionate to the evaporating surfaces. Some authorities claim that a sort of suffocation follows when the air does not circulate in the silos, and it is maintained that beets in a badly ventilated atmosphere of less than 4° C. undergo a considerable vital change, resulting in much more serious complications during sugar extraction than those due to overheating. When considering this question of beet keeping it must be remembered that these roots cannot be stored under the same conditions as are fruits, etc., which demand dry air, while in the case of beets the air may be comparatively moist, but must be constantly renewed. The question of evaporation is more important than is generally supposed. If it goes beyond a quarter of the total weight, the beets cannot be subsequently handled in the slicer. Evaporation is to be dreaded even before siloing, and therefore the beets should not be left unprotected upon the fields after harvesting, but should be covered with their leaves without delay. During the siloing beets should not lose more than 12 per cent of their water through evaporation.

**Ventilation.**—In order to protect the beets from the sun during the first stages of the campaign large sheds are used in which ventilation must be effected, otherwise there would be a rise of temperature in the mass. This question of ventilation has been the subject of discussion during a period of fifty years. One fact remains certain, that during the breathing of the beet carbonic acid gas is liberated, and this must be eliminated, otherwise complications vital to the plant will certainly follow.

**Loss and increase of weight during siloing.**—At the Escaudœuvres * (France) sugar factory an increase in weight of 4.5 per cent was noticed, due to the water absorbed after a rain.

* B. Syn., p. 1030, 1899–1900.

CLAASSEN * made the same observation. It is mainly those beets that come directly in contact with the moisture of the soil or rain that increase in weight, especially when they have been harvested during dry weather. The loss of weight may become considerable when the harvesting and siloing are done during rainy weather. Excessive ventilation of the silos is also responsible for considerable decrease in weight during storage.

BRUNEHAUT † says that the loss of weight in the silos may reach 5 to 6 per cent. All facts considered, this is a consideration for which due allowance must be made in experiments for determining what method of siloing will lead to the best results. If no allowance be made for these transformations, a smaller loss would appear than practical experiments would subsequently show.

**Essential conditions for keeping beets.**—In order to keep beets in a proper state of preservation during the several months of the campaign the essential conditions are, protection against frost and low temperatures, heat, and rot. It is for the protection against the low temperatures that most of the precautionary measures are taken. The methods adopted are examined in detail under another caption.

Every variation of temperature of the exterior air manifests itself in the interior of the mass of beets, and this influence is evidently greater if the pile of roots is not covered or if the ventilation is exceptionally active, due to the exposure of certain portions of the interior to the air. As heat is generated during the beet's respiration, it necessarily follows that the temperature in the interior of the silos is greater than the average outside temperature, the difference depending upon the extent to which the air circulates between the roots.

GROUVE ‡ urges that the silos should be ventilated in such a way as to keep their temperature below 2.5° C. Air is injected into the mass and circulation is accomplished either by means of a fan or a pump, thermometers being placed in the interior of the mass, by which the temperature may be accurately regulated. The best mode, however, consists in the use of suitable chimneys through which the moisture can escape freely. As soon as the temperature has fallen in the interior of the silo the vitality of the beet is considerably diminished, and if all influences of ambient temperature

* Z., **45**, 204, 1895.
† B. Syn., **29** to **35**, p 1024, 1899–1901.
‡ Z., **30**, 836, 1880.

are removed the beets cannot become heated, provided, however, that the mass of roots is not too high. CHAMPONNOIS * suggested that silos should be actively ventilated from the start, and that when the mass is at 0° C. communication with the outside air be cut off. The question of silo ventilation has been very thoroughly discussed by LANGE,† who calls attention to the fact that if ventilation is poor the beets will shrink and dry. HERZFELD's recommendation to give the beets during storage the minimum amount of air necessary to maintain their vitality has already been noted. An increase in the volume of air tends to increase the sugar loss.

The whole question of silo ventilation remains an unsolved mystery as far as the arguments pro and con are concerned, for no sooner is one issue settled than other arguments are brought which are most difficult to refute. For example, CLAASSEN ‡ denies absolutely that ventilation is at all necessary, and maintains that among its objectionable features is the abnormal drying of the beets, under which condition they appear to lose less sugar. On the other hand, if beets are siloed with an excessive amount of adhering earth, even when well ventilated, the air finds obstructions to its free passage and the ultimate result is the same inferiority as with the non-ventilated silos. Among the objectionable features of the excessively ventilated silos which should not be overlooked may be mentioned the fact that frequently some portions receive too much air and others not enough.

The advantages of low temperatures for beet keeping were long ago urged by the writer, and years afterward BRAUNE §, and later still CAMBIER, proposed to keep beets at low temperatures, using for this purpose refrigerating appliances giving a temperature of $-2°$ C. Experience shows that machines accomplishing this work may be had in France at a cost of about five dollars for each ton of beets stored. Making allowance on the investment for the sinking fund, the subsequent working of the plant may be conducted on a basis of less than one dollar a ton. While this method may be desirable in exceptional cases, it is doubtful if the advantages claimed exist in general.

**Influence of heat from soil radiation.**—There is certainly some truth in the idea that the heat radiated from the soil must necessarily have a certain influence upon the keeping of beets for a

* La. S. B., **20**, 256, 1891-92.
† Z., **34**, 712, 1884.
‡ Z., **40**, 154, 1890.
§ S. I., **42**, 451, 1893.

given period, and in order to overcome this effect it has been proposed to cover the bottom of the silo with ashes or asphalt. In some cases this plan has been put into actual practice. The idea of VIBRANS * is one of the most original coming under the writer's notice. It consists of arranging under the silo a series of air passages which communicate at its two extremities with the ambient atmosphere. Under these conditions the hot air escapes freely. The idea of filling these passages with some non-conducting substance is a new departure and offers some advantages, but objections to it may be urged. As one square meter of soil throws out only 400 calories in two months, as shown by FOURIER's experiment, and the beet during this interval develops within itself 40,000 calories, the great disparity in the two figures evidently renders surface isolation useless. If the soil is considered as a non-conductor, we approach very near to a true solution of the problem.

**Prevention against rot.**—Of all the modes to prevent rot none appears to be better than a low temperature; but this means is necessarily only temporary, as numerous micro-organisms are not killed by low temperatures. Antiseptics, such as phenic acid, naphthaline, and sulphophenol, have many advantages. Experiments in this direction are numerous, but cannot be discussed at present. Among the investigations that at first promised to lead to some important results may be mentioned those of LACHAUX,† who uses for the purpose phenic and boric acids. It must be noted that the results obtained were far from satisfactory, because the water used in preparing the chemicals had an important influence on the beets.

**Requisite conditions for siloing.**—It is essential to the satisfactory siloing of beets that the harvesting be not too long delayed, that all mutilated or bruised beets be rejected, and that the siloing be done during cool but not frosty weather. In Europe the beets are never harvested much before October.

**Silos.**—Beets are kept best when covered with earth in comparatively small silos, and therefore selected mothers that are to be used for seed are placed in diminutive ones. It must be noted, however, that this mode is not practical when the roots are intended for the factory, in view of the great expense involved and the space required.

* N. Z., **27**, 139, 1891. † B. As., **11**, 516, 1894.

The construction of silos is very varied, depending upon the purposes in view. They may be located either on the fields near the place where the beets have been cultivated or in the yards of the factory. The conditions and requirements in the two cases are not the same. For instance, if the farmer has an agreement with the manufacturer to deliver only at such periods as ordered, the solution of an entirely different problem is presented than when the roots are piled up in the yards of the factory. In both cases the cubical contents of the piles should be kept within reasonable limits, so that if any organic changes occur, due to faulty methods or from other causes, the loss may be kept within bounds.

**Precautions in constructing a silo.**—Many circumstances may present themselves. If the silo must be built against a stone wall, it is better to place a layer of straw between the wall and the roots. When silos are of a considerable length they should be divided by suitable walls.

**Soil for silos.**—All soils are not equally suitable for silos. The most desirable soil is one that is reasonably dry, for with moist soils complications are sure to arise in the mass of beets. The land should be on a slight slant, facilitating drainage at no expense.

**Height of piles of beets.**—Experience shows that a beet pile should never be more than 3 meters high, otherwise the lower roots would be crushed and subsequently rot, fermentation being followed by a rise of temperature in the entire mass.

**Direction and position of silos.**—Whether silos are built on the fields or at the factory they should be so situated as not to be exposed to a broadside attack from the cold winds. If this cold air strikes the beet pile on the side of its smaller dimension, the harm done is reduced to a minimum. The same argument applies to the location of a beet shed. Without doubt the argument for a north and south direction is most plausible, for the solar rays have then less effect than they would if the pile were built east and west.

**Position of silos.**—The farmer is interested in reducing to a minimum the work that is awaiting him in the future. If the piles of beets are made on the fields in proximity to the place of harvest, the hauling during bad weather will be much more difficult than if they be placed near the main roads leading to the factory.

Among the interesting types of cellar storage may be men-

tioned the OHE* method. These silos are 3 to 4 meters in width and 3 meters in depth. At the bottom are strips of wood that prevent direct contact between the beets and the soil. The piles are 4 meters in height. Owing to this excessive height ordinary silos constructed upon the ground without any special preparation, and having a simple covering of straw or earth, actually give better results in the comparative tests than the expensive 3-meter subsoil arrangements. It was shown that the sugar losses were twice as small in the ordinary silos.

**Beets kept in earth.**—A simple earth protection to keep beets in a satisfactory state of preservation has stood the test of generations and continues to have numerous advocates. SILBERSCHLAG † even recommends that dirt be thrown in with the beets during their keeping. Among other advocates of this mode may be mentioned KLAMROTH and VON ORLANDO. Most satisfactory results may be obtained by making alternate layers of beets and earth. Especially does this mode offer important advantages for farmers handling small masses of beets, but it is of little or no interest where manufacturers, as is frequently the case, have thousands of tons to keep for months at a time.

**Silos covered with earth** are simple in their construction and advantageous to all interested. In some cases only a small ditch is made, and in others the surface of the ground is taken as a base. The size of these silos is extremely variable. One type coming under the writer's notice was 6 meters wide, 3 to 4 meters high and 100 to 200 meters in length. They have suitable means of ventilation at regular intervals, and the condition of the mass of beets is made evident by the color of the escaping vapors. In France satisfactory results have been obtained by making the silos 3 meters at the base and 2 meters on top, and thoroughly covering with earth.

**Examples of good types of silos to be built on the beet fields.**—The silo shown in Fig. 2 is built on the surface of the ground by placing a plank in the direction in which the silo is to run. This will form the centre of the bottom of the pile, and upon it are placed two other boards forming an angle. At distances of about 4 meters vertical openings for the circulation of air are placed, as shown by the arrows. On the other hand, when the beets are soon to be ordered to the factory they are simply piled up on the

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* Z., **39**, 573, 1889. † Z., **24**, 390, 1874.

ground (Fig. 3), forming a sort of triangular prism and then covered with straw, the thickness of which depends upon the ambient temperature. The height in this case is about 1 meter, and the

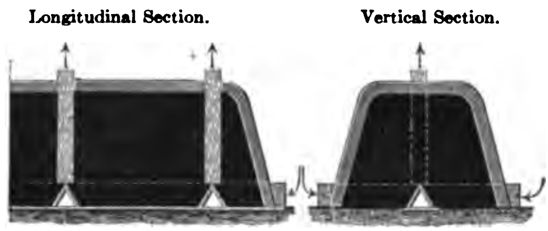


FIG. 2.—Good Type of Silo, Ventilation being Well Understood.

length is variable. The beets are removed from the ends as needed and the remainder is at once covered with straw. When the roots are to remain in the pile for a period of weeks certain precautionary

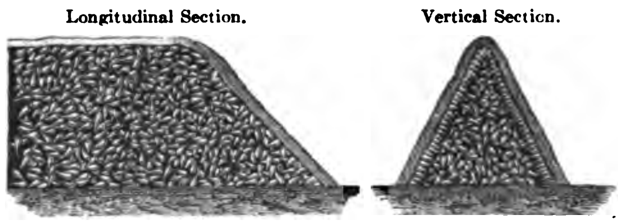


FIG. 3.—Roots to be Utilized Shortly, Piled on the Ground with a Slight Covering of Straw.

measures should be taken for their drainage. The arrangement shown in Fig. 4 is very practicable. A ditch of 30 cm. is dug in the ground and about 30 cm. further along, and extending completely

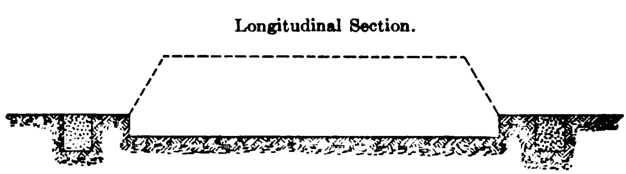


FIG. 4.—PAILLY's Idea, Facilitating the Drainage.

around the first ditch, another one is made only 15 cm. wide but 50 cm. in depth. This ditch is filled with stones and serves to carry off all the water that may filter through the soil. This plan presupposes a porous soil, otherwise the drainage should be from the bottom and centre of the pile. Drainage may be accomplished

on a hill in the manner shown in Fig. 5, the upper drainage being to collect the water running from the straw and earth covering. Numerous other conditions may present themselves, but are of only secondary interest.

**Piles of beets.**—In California, owing to the mild climate, and in other countries where the campaign is very short, the beets are simply piled up in the yards of the factory, and it is regretfully noted that less and less precaution is taken for their preservation. Beets will readily withstand a temperature not far from freezing provided they are permitted to thaw gradually. Severe cold and exterior heat penetrate into the interior of the mass very slowly, and it is only those beets that have been actually frozen, and whose

FIG. 5.—Silo on a Slant, Preventing a Deposit of Water.

cells containing the saccharine fluid have been broken open, that suffer from the influence of frost, and this takes place only in case the cold has been very severe and sudden changes in the temperature have occurred. In countries of average temperature these losses need not be considered, as they are small compared with the mass of roots that keep well. In climes where early frosts occur it becomes important to thoroughly cover the beets. Under these conditions large silos or beet cellars of considerable dimensions are used. MALANDER says that in Belgium it is the custom to pile beets up in the yards of the factory to a considerable height and without any exterior covering. If the area desired can be obtained the height of these piles does not exceed 2 meters. This method is faulty, and the manufacturers have long since admitted that such is the case, but do not appear inclined to make a change. Though this apparent neglect exists they have an excellent custom of slicing the beets in the order in which the piles were constructed. Exceptions are made to this rule, however, in cases in which certain piles show signs of some important organic change. Piles about 6 meters wide appear to meet

the requirements of the situation. In unloading it is considered advantageous, as the space is frequently limited, to keep the sides of the pile vertical, but this mode presents the disadvantage of involving very high labor expenses. Precaution is taken in these vertical piles to keep the necks of the beets pointing to the exterior. An excellent measure for preventing the rotting of beets in piles is to turn them over at regular intervals. This plan is without doubt to be recommended, but is hardly practicable in this country owing to the expense. Argue as one may, the sugar losses in these unprotected silos are very much greater than is generally supposed. According to BRUNCHANT* they may attain at least 1 per cent more than in the well-built silos. Underground cellars, which have long been advocated by the writer, offer advantages for cold climates, and while their construction is very expensive, it must be admitted that their ventilation and temperature may be kept under accurate control, and that there is only a slight motion of the circulating air. With the view to taking some precaution for protecting beets where no sheds exist, tarred cloths that keep out moisture are used. In Belgium cloths that have been used in the filter press answer the purpose. In some factories the covering consists of straw, bamboo, rush, cane reed, forming a sort of matting, which is made at the factory.

**Sheds.**—At many of the large factories sheds are used to cover the piles of beets so as to keep them in first-class condition until used. This plan is very economical and offers certain important advantages. In France the cost of such sheds is less than three dollars per square meter. To protect beets against the winds, which means that the temperature of the mass of beets is raised or lowered to the same degree as the ambient temperature, one sugar factory visited by the writer used economically constructed closed sheds. The sinking fund necessary to establish this method represented about 25 cents per ton of beets sliced. In France it is admitted that the sheds for small factories should have a superficial area of about 6 square meters per ton of beets to be sliced, but this rule could not possibly be applied to a 500-ton plant. Some authorities state that a ton of beets emptied into a shed occupies a volume of 1.80 cm., consequently a cubic meter of beets weighs 555 kilos, and this forms a basis for calculating the cubical contents of the sheds. In these sheds beets are piled

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* B. Syn., **29** to **35**, 1024, 1899–1901.

up to a height of 3½ meters, and under these conditions 2 tons of beets per square meter of surface may be stored until needed. Attention should be called to the SIMON * shed, which may be taken apart and put together at will. The tar-covered cloths must be used as an outer covering, leaving spaces at intervals for the circulation of air. A silo of an emergency type that may be built as the occasion demands was devised by PETIT.† Posts are sunk at regular intervals to support the framework of the roof. The beets are piled to a height of about 4 meters, the necks placed outward and forming the exterior sides of the pile. As the work progresses the frames are placed in position, and earth is piled up outside tapering toward the top. The roof frames are made solid by cross ties consisting of wooden slats, the roof being covered with straw or some similar substance. It is important to note that, with some slight variation in the details, sheds of this kind have been adopted by several beet-sugar factories of the Western States. The width of the beet sheds used in France varies from 10 to 20 meters. Upon general principles it may be said that 15 meters fits all possible conditions, and permits the use of all the standard commercial sizes of material. The height under roof frames varies from 3.5 to 5 meters. A suitable galvanized iron framework with a cardboard covering permits of broad space and the free circulation of cars and carts between the vertical supports. American experience differs from that of Europeans as regards sheds, and in California, where the sugar campaign is conducted without fear of frosts, the problems differ greatly from those of the colder states. For example, in Utah the first sheds built for beets were 500 feet long and 26 feet wide, and were made of wood and lined with straw. In regard to these sheds the manager of the factory subsequently wrote: ‡ "We have discovered since then that frost is something we are not afraid of, provided our beets are brought here in a perfect state. We have now erected several platforms, one of which has sides, but the top is left entirely open. It is 500 feet long by 34 feet wide and will hold fully 3000 tons of beets. This system has worked admirably, and the beets which kept the best were those that were left entirely open to the weather. The system of storing in large open piles has proved satisfactory under

* La. S. B., **21**, 362, 1892–93.

† B. Syn., **14** to **16**, 179, 1893–1894.

‡ MYRICK, The Sugar Industry.

the conditions here. We have stored some 6000 tons of beets in piles on bare ground. When the frost came and we had a temperature as low as 10° below zero the surface of the stored beets froze to the depth of two or three layers of beets."

**Economical considerations.**—The silo should be such that the beets lose the least possible amount of sugar during their keeping, and that the work of opening the silo and handling the roots be done at the least possible cost. In short, the sheds for keeping the beets should be of an economical construction.

CLAASSEN * estimates that the loss of sugar in the uncovered piles of beets is about 1.5 to 0.7 per cent, and he concludes that no shed combination, even at the cost of $1.40 per square meter, is sufficiently economical to warrant its construction. To avoid the expense of beet storage many German factories and all the sugar plants of Sweden allow the farmers a certain compensation for beets delivered during the progress of the sugar campaign, that is to say after November 15. This premium amounts to considerable, and from all calculations made in such cases it appears that the factory would have every monetary advantage in constructing sheds and silos of its own. The farmers in such cases seldom take the trouble to construct silos, and the beets are exposed during the interval between harvesting and the time they are ordered to the factory, resulting in changes in the roots which in the end are a decided disadvantage to the manufacturer. In some cases still another mode has been adopted, which is to allow the farmer a certain sum per ton for the construction of the silo in question. Where this idea has been carried out the silo frequently used is of a very simple construction, being merely a trench into which the beets with their leaves are thrown. The water from these silos is drained through a furrow made with a plow. The farmer, from his point of view, also has arguments against the delivery of roots at any given date; for example, if the weather continues warm after the period of harvesting, the question of preservation is then as important to the tiller as protection against excessively low temperatures.

**Sugar-beet drying.**—Of late the question of fresh-beet cossette drying has been seriously discussed, and the excellent apparatus of LAFEUILLE gives very satisfactory results for this purpose. The dried slices may be kept until needed. This idea was worked

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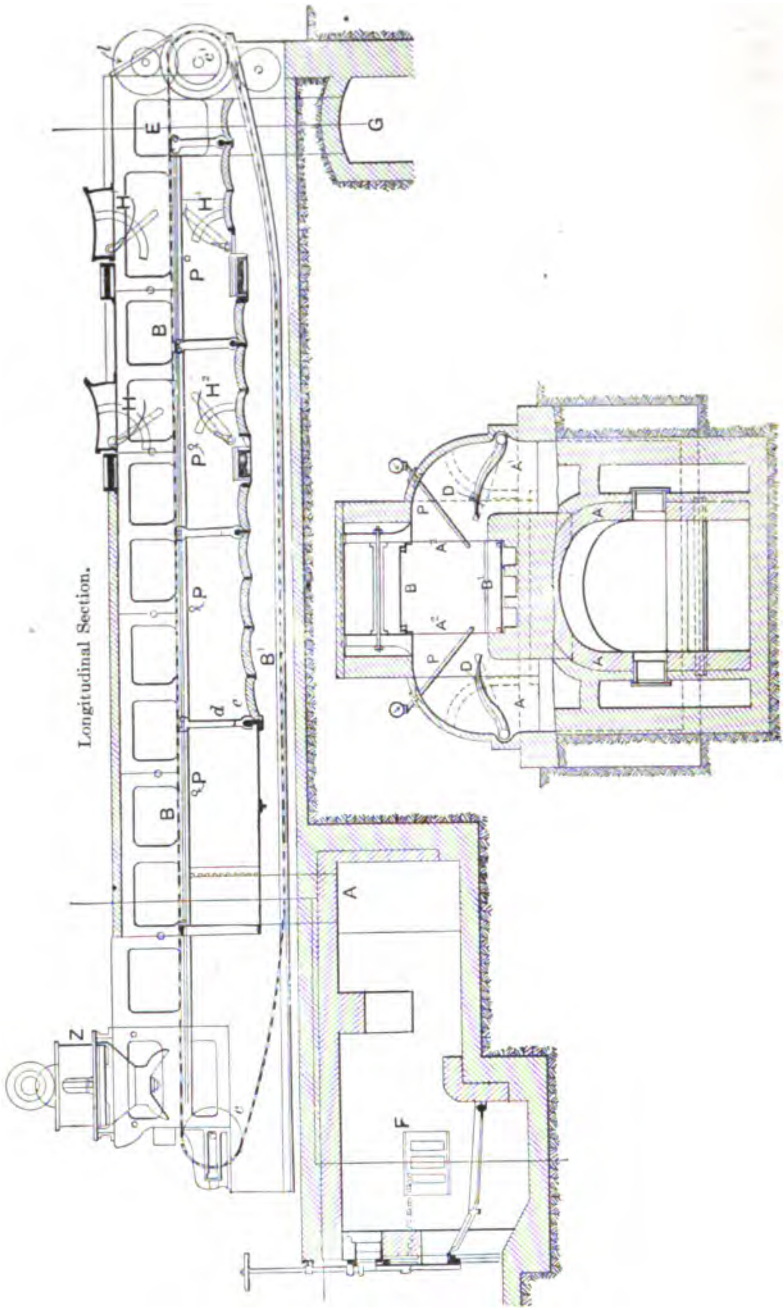
* Z., 45, 204, 1895.

out on a practical basis by Schüzenbach in Austria many years since; but it was soon discovered that the plan was not economical, as the cost of fuel for the evaporation of a product to which water would be subsequently added and again evaporated, was not compensated for by the advantages gained. In California sun-drying has been tried, but has led to only very indifferent results. The Lafeuille mode is simple and should be described in detail.

The drying is effected with hot gases that produce at the same time a sterilizing effect on the cossettes. A longitudinal section of the dryer is shown in Fig. 6. The sterilization is accomplished by bringing the beet slice in contact with gases at the temperature of 500° to 600° C. These hot gases are from the grate *F*, Fig. 6. They circulate through the flues *A*, then in $A^1$ (see section through *AB*), and finally into $A^2$, beneath the moving apron *B* (see Fig. 6), the lower part of which passes into *B* after having passed around the drums *CC*. This endless moving apron *BB* has suitable rollers along its lower surface, which facilitate the motion. The gases, upon entering the portion of the dryer in which circulates the movable band, are kept under control by suitable registers *D*, which permit one to regulate the section of the flue. The temperatures are given by the pyrometers *P*. To the hot gases, after leaving the fire grate *F*, are added certain sterilizing gases or vapors (as, for example, sulphurous acid, obtained by simply throwing into the fire a small quantity of sulphur), whereby all the germs and ferments that the cossettes may contain are destroyed. There follows a coagulation of the albuminoids and pectic substances. The sterilizing and desiccating gases escape through the flue *G* connecting with the chimney. There are several registers which regulate this exit, one of which is shown in $H^2$ and $H^3$. The beets are thrown into the hopper *Z*, feeding the slicer underneath, so that the resulting slices fall directly upon the endless band *B*. The dried cossettes are thrown out at the other end of the dryer. The bar *l* falls very close to the dried product and prevents the gases from escaping in that direction, and as a consequence they find an exit passage at *E*. Of late certain changes have been made. The beet slices are collected on suitable cast-iron boxes, 1½ feet in width and 2 inches in depth, spread evenly upon these and then placed on the moving apron *B*, and removed at the other end. This arrangement does away with a very objectionable feature of the previous combination, which prevented the dried cossettes from adhering to the moving band, notwithstanding that the surface was well brushed. Some




Vertical Section through *AB*.

FIG. 6.—LAFEUILLE Cossette Dryer.

success has already been realized by drying slices of the forage beet for cattle feeding, 150 tons of the sliced roots being dried per diem. Experiments on an extended scale show that 1000 kilos of beets, containing 13 per cent sugar, 8 per cent non-sugar and 79 per cent water, may be reduced in the LAFEUILLE dryer to 250 kilos, the product will contain 52 per cent sugar, 32 per cent non-sugar and 16 per cent water. It is estimated that upon an average 4000 to 4350 kilos of fresh beets will yield 1000 kilos of dried product, and even when containing 15 per cent water they will still have excellent keeping powers. In Spain some results have been obtained by semi-drying and sterilization, and then completing the drying in the sun. By this mode, instead of consuming 75 kilos of coal per ton of beets being dried, the desiccation was accomplished with 15 kilos of coal. For working the dryer under consideration there is needed 125 HP. The fact is that to conduct the dryer under satisfactory conditions a capital of not less than $100,000 is necessary. The cost per ton of beets dried is about $1.60, including fuel, motive power, sinking fund, general expenses, etc. The ton of dried product cost $6.20 or $20, including the cost of the beets used. It is claimed that this product offers advantages for cattle feeding not found with many of the molasses combinations.

**Utilization of frozen beets.**—HERISSANT* recommends that thawed beets that have shown no signs of decomposition, but which cannot be sliced, be carefully washed, cut up and mixed with chopped straw. After three days the combination is to be salted and placed in suitable silos, and subsequently used for feeding purposes. The same idea was advanced by HOLLRUNG, who urged that special precautionary measures be taken to keep out the air.

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* J. d. f. d., S. Jan. 1890.

# CHAPTER III.

## TRANSPORTATION.

**Different methods of transportation.** (Fig. 7.)—The transportation of beets from the silos to the washer may be accomplished either by wheelbarrows, carts, overhead wires, cars on narrow-gauge tracks, mechanical traction or hydraulic transportation, according to the various circumstances involved. The first two modes are very primitive and need not be especially considered. The overhead wire was recommended as early as 1872 by KERSTEN,* and may render excellent service if the site of the factory involves different levels and is at a great distance from the silos.

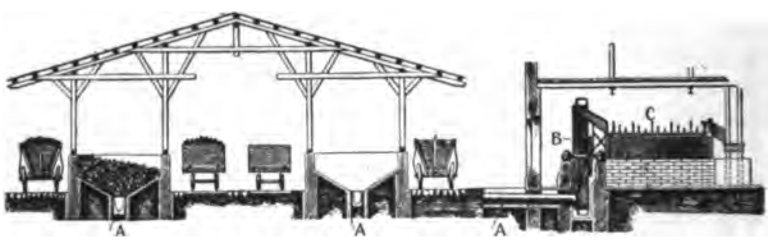



FIG. 7.—This Transverse Section shows the General Arrangement of the Reception Sheds, Beet-washers, etc., described in Chapters II and III. *A*, flumes under beet sheds and leading to lifter; *B*, wheel or other lifting device for delivering beets into the washer *C*.

**Small cars.**—The small cars of the DECAUVILLE type previously mentioned have rendered excellent service since 1875, when they were first used as an economical means of transportation at sugar factories. The tracks are the narrow-gauge 0.50- to 0.60-meter types, and either movable or fixed. At the present day, if hydraulic transportation is not used, this mode, from an economical standpoint, is to be recommended. The evident advantage of the movable track is that it permits one to meet numerous emergencies that

* Z., 22, 621, 1872.

may present themselves. Beet piles of considerable size are frequently built over the permanent tracks which come into use as the volume of the beets is reduced. The best method, however, is to have the farmers pile up the beets in the yard of the factory, leaving a sufficient space between the silos for the free circulation of the carts. Before piling up any beets it is recommended to place in position the movable tracks that are to be subsequently used. In order to do away with curves of very short radius which frequently cause subsequent trouble, KARLIK * does not place the silos perpendicular to the principal track, but at an angle, shown in Fig. 8, that facilitates switching.

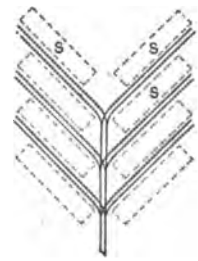


FIG. 8.—Position of Silos Connecting with Main Track.

The narrow-gauge transportation for beets has been perfected in recent years by KOPPEL. By this method cars of 5-ton capacity which may be emptied by being turned over can be used. For hauling these cars, overhead trolleys, or in some cases electric locomotives, give satisfaction. It must be noted that these means of traction are valuable only when the distances are too great for the practical utilization of hydraulic transportation.

**Belting.**—Special rubber belting suitably arranged was the principal means of transporting beets from the silos to the washer in Europe until 1880. Later a sort of iron belting, with special attachments at regular intervals for separating the earth adhering to the root, was introduced. This lessened the work during washing, and another excellent feature of this mode was that in a special emergency † the belting could be changed into a carrier slanting at 45°, by means of which the beets could be emptied directly into the washer.

**Flumes.**—Nearly all other methods have been superseded by hydraulic transportation, which was first introduced in Germany by RIEDINGER ‡ in 1879. During the same year a practical application was made of the method at Bok, Hungary, and for many years past it has been generally used and is a pronounced improvement over all other methods. In some cases it has proved practicable even at distances that at one time would have been thought far too great for its application. In most of our Ameri-

* Z., **27**, 202, 1903.. † Z., **24**, 347, 1874 ‡ Z., **30**, 703, 1880.

can factories the canals are of wood, or in some cases ditches are dug in the ground. There is evidently a future for the sheet-iron section method; the sections may be unmounted and screwed together and offer many other advantages, as they are readily placed in new positions at very little cost, may be used to carry beets from the yard to the factory, and also be put out of the way during those periods of the year when all approaches to the factory are being put in order for the coming campaign.

The Riedinger mode of transportation consists of a flume or sluice slightly inclined, in which water circulates with sufficient force and velocity to carry the beets to the factory. The plan and section in Fig. 9 shows the earliest arrangement for

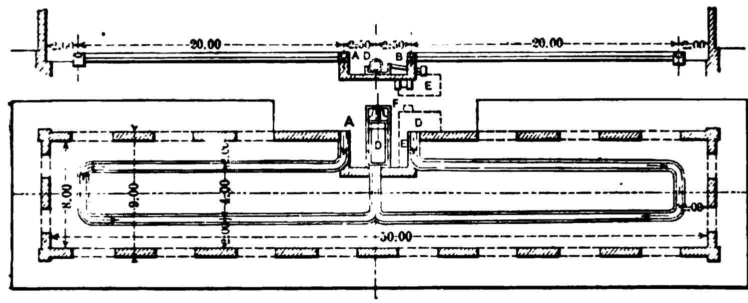


Fig. 9.—Plan and Section of the Riedinger Silo with Flume Distribution.

bringing the water into the flumes from outside of the beet sheds. The water enters at *A* and *B*, circulates under the beets in the flumes and finally passes through the washer *D*, and then into a pit, *E*, from which it is pumped out to be again utilized. While this arrangement has undergone many modifications, the main principle has never changed. The roots are thus conveyed at a very slight expense, only two men being needed for a 500-ton plant. In certain special cases the saving effected is 80 per cent of the expense of obsolete methods. The cost of hydraulic beet transportation in France and Germany is about six cents per ton, which is 50 per cent less than by the old methods.

Among the numerous advantages of this mode the beets have most of the adhering dirt removed during transportation. All of the sand is washed off, but some of the clayey earth, being sticky, remains on the surface of the roots and must be removed in the washer.

**General facts relating to hydraulic transportation.**—The canals are placed in the middle of the beet sheds or silos, and if the plans

have been properly made the carrying may be very economically accomplished. The slanting sides of the sheds feeding the canal may be constructed of boards with spaces between them, permitting some of the adhering dirt to fall through before reaching the canal, thus obstructing the circulating water less and permitting a longer interval to elapse before the necessity of cleaning the canal arises. Furthermore, it frequently happens that the reservoirs for the residuary water of a beet-sugar factory are of only moderate dimensions, and all additional impurities add just so much to the difficulty. Unfortunately, however, the spacing formed by the laths, boards, etc., becomes clogged when the beets are more or less covered with mud during rainy weather and no longer answers the purpose.

Flumes placed beneath the surface of the ground necessarily must be specially adjusted to the various conditions of each installation. Flumes outside or under the silos and sheds should be placed at the bottom of a ditch or between two inclined planes. These slanting surfaces are either brick or cement, their width and size depending very much upon one another and upon the volume of beets they are intended to carry. An excellent arrangement is shown in Fig. 10; the flume itself is built of brick, lined with

FIG. 10.—Section of Flume under Silo. (An excellent French type.)

cement, and the sides directing the beets are also of stone construction. The arrangement shown in Fig. 11 is not so good, for the dirt from the sides finds its way into the flumes from top to bottom. The slanting sides vary from 3 to 8 meters. The slant should be such as to permit the beets to slide into the canal by their own weight without any other assistance. However, when the slanting sides are very far apart, in cases of very large sheds, they may attain a greater height than the carts from which the beets are delivered, under which circumstances, as may be imagined, the unloading would be difficult and in many cases impossible. For this reason it is

suggested that with less of a slant the beets may be pushed into the sluices at a very slight expense.

LALO * recommends that the incline connecting the silos with the canals slant 20 cm. per meter. When the slant is excessive the beets are most difficult to handle at the receiving station. An inclination of 30° is apparently sufficient. The length of the canal depends upon its slant per meter and should be proportional to the size of the sugar plant, so that the mass of beets may not become overheated by the warm vapors arising from the canals,

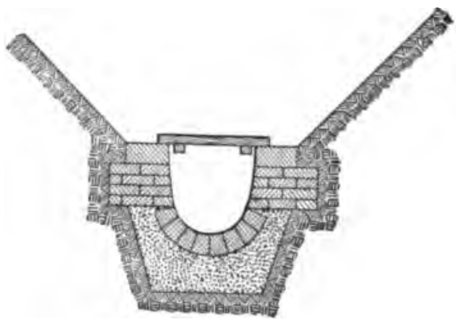


FIG. 11.—Section of Flume under Silo. (Type not to be recommended.)

which, after several days, might cause serious complications. Under all circumstances every possible effort should be made to renew all the beets in the flumes every few days.

**Shape.**—The shape of the flumes depends upon many factors, among the most important of which are the supply of beets needed at a given point, the variable condition of the roots as regards adhering earth, etc., the volume of water that is readily available for floating the beets and the slant that may be given to the canal. The sizes most frequently adopted for an average sugar factory, say for 500 tons per day, are very varied. Among the earlier styles may be mentioned the R. BOSSE † type, in the shape of a square with rounded sides 340 mm. deep. Experience soon showed the importance of increasing this depth, as under certain circumstances an obstruction was likely to occur, causing an overflow. RIEPENHAUSER ‡ recommends that these flumes have a height of 400 mm., while, on the other hand, CLAASSEN advocates a height of at least 500 to 600 mm. with a rounded bottom, the width depending upon

* B. As., 9, 89, 1891–1892. † D. Z. I., 6, 455, 1881. ‡ Z., 31, 979, 1881.

VARIED FRENCH TYPES OF FLUMES.

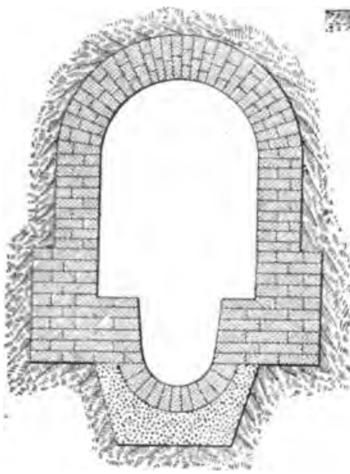


Fig. 12.—Concrete Foundation entirely Underground.

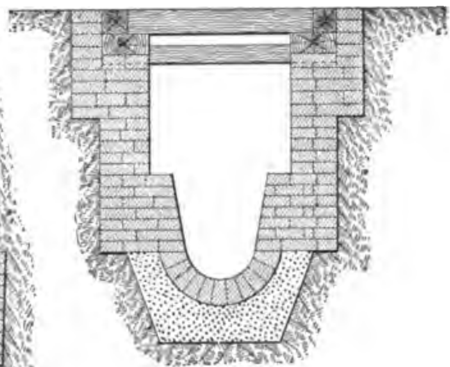


Fig. 13. — Concrete Bottom Foundation, upper part open.

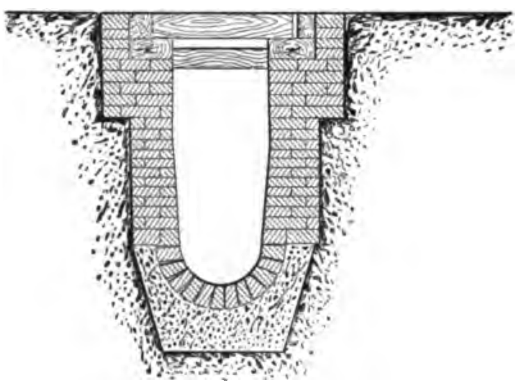


Fig. 14.—Upper part open.

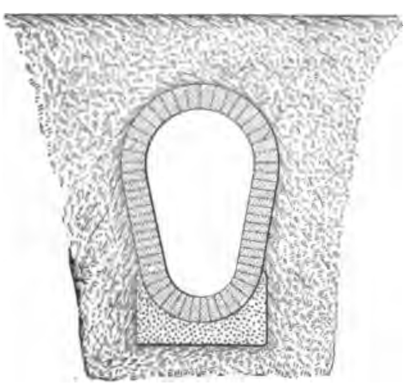


Fig. 15.—Underground.

the volume of roots to be handled, and varying from 300 to 500 mm. However, in special cases, where the canals must be placed considerably beneath the surface of the soil, the sides may be made vertical (Figs. 12, 13 and 14), taking the precaution to leave a projecting portion near the bottom on both sides, upon which the workmen may walk when cleaning out the canal. In some cases the canal is circular, but experience seems to show that there are greater advantages in having it oval (Fig. 15), so that if the volume of water is limited the velocity of the circulating water may not be lessened, or at least not diminished sufficiently to reduce the work performed

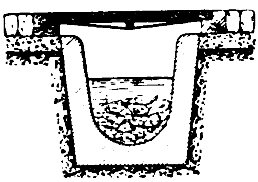


FIG. 16.—German Type.

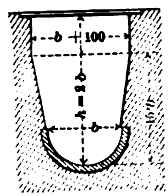


FIG. 17.—HEINZE Type.

below the desired standard. The sides of these flumes are not vertical, so that if for one reason or another an obstruction should occur at the most elevated portion of the sluice, the tendency would be to slightly raise the beets and carry them forward without difficulty. Fig. 16 is a German type. According to HEINZE * the most desirable proportions are those shown in Fig. 17. For an inclination of 10 mm. per meter (Fig. 17) $b$ is calculated in the following manner. $Q$ = volume of water that may be used per minute; $R$ = quantity of beets sliced at the factory per diem expressed in centners of 50 kilos, $b^2 = \frac{Q}{400}$ decimeters or $b^2 = \frac{R}{1330}$ decimeters. KARLIK † recommends flumes having a semi-elliptical section with a large axis of 120 cm. and a small axis of 40 cm. It is to be noted that the actual working sizes of the various flumes do not differ to any extent in the various factories. The cross-sections remain about the same for large as for small factories, though the volume of water needed may be somewhat greater and a washer be fed by two or three

* C., 10, 843, 1902. † B. Z., 27, 207, 1903.

of these flumes at the same time. It is customary to keep the size within the limits of the dimensions given, which may be accepted as those in general use. When the beets are very dirty narrower and deeper flumes are usually built. Evidently the cleaner the beets are the greater will be the carrying capacity of the sluices, which depends also upon the volume of water and the slant of the flume. Sometimes the section of the sluices at the junction of the curves is increased.

**Building flumes.**—The *materials* used for the building of flumes are very varied, wood, brick, stone, iron, etc., being used, though wooden flumes are exceptional and only for temporary use. The principal objection to wood is the friction offered to the circulating roots, but in this connection it is important to note that some years since Trocme made wooden movable flumes which met with reasonable success. Frequently the flumes are made entirely of brickwork, either the standard variety or a special kind, which is then covered with hydraulic cement. The sluices constructed in this manner have several objectionable features, as, for instance, particles of cement break off and the rough surface offers an objectionable resistance to the motion of the roots in the flumes. The difficulty is greater during very cold weather, and it is desirable after the sugar campaign has ended that the flume be covered with straw or barnyard manure, until the cold season is over. The cost of repairing these flumes is considerable, and this item added to the cost of the first installation sometimes renders the hydraulic mode of transportation very expensive. Without doubt the sluices made of cement and concrete are the most economical in the long run. De Malander says that these sections may be constructed at the factory during the summer months. They may be made of solid concrete 70 to 80 mm. in thickness, using for the purpose a wooden form into which a mixture consisting of 1 part cement and 2 parts gravel is emptied. After the product is dry, or at least perfectly settled, the moulds are taken apart. In the thickness of the cement should be left a projecting portion that will form a point for one section with another, each section being about 1.25 meters long. Another mode consists in having a wire framework covered with cement. In this case the portion forming the joint should not be thicker than 25 mm. and the length of the sections may be 2.50 meters or twice that of the former type. These cement flumes are simply placed on a layer of concrete 10 cm. in thickness, and into the sides either earth or concrete

is compressed. On the other hand, KARLIK says that the best mixture for such sections made at the factory consists of one part cement and six parts of sandy quartz, for which may be substituted three parts sand and three parts small stone, water being added until the mass has a pasty consistence, and with this the bottom of the flume is made and placed in position at the bottom of the ditch in which the flume is to be constructed. Upon this bottom is placed an iron form *WAI* (Fig. 18), representing the interior profile of the flume to be constructed, leaving between the earth surface, *E*, and the form a space which represents the thickness of the sluice, 12 to 13 cm. probably giving the best results. The concrete is compressed into this space and on the top are placed the wood strips, *W* and *I*, upon which rest the wooden or iron gratings covering the flumes.


FIG. 18.

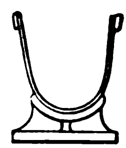


FIG. 19.

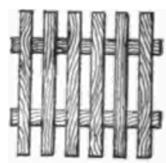


FIG. 20.

FIG. 18.—Showing Position of Iron Form during Concrete Drying.
FIG. 19.—Sheet- or Cast-iron Flume.
FIG. 20.—Wicker Covering.

After a time the iron moulds are withdrawn. These sections are from 1 meter to 1.25 meters in length. The work may be rapidly executed, and has the advantage of being strong and needing little or no repairing. Its first cost, however, is greater than the modes previously mentioned. In certain cases terra-cotta is preferable to cement for the bottom of the flumes, as where the dirt adhering to the beets consists of gravel, which would tend to rapidly wear the cement. Such special sluices consist of semicircular terra-cotta (Fig. 18) pipes with enamelled interior surfaces, the sides of the sluices being either concrete or brick. As their inner surface is smooth they offer no resistance to the beets during transportation, and this mode is in the end economical. In all cases they cost less than the sheet- or cast-iron semicircular sluices (Fig. 19). With such sluices a depression should be made on top as a rest for the upper cover.

Generally the flumes have for a top covering either a wicker (Fig. 20) or cast-iron grating (Fig. 16), or sheet-iron covering, sufficiently strong to resist the vertical pressure of the pile of beets placed above. These coverings must be of a size to permit ready handling. When they are of iron, holes at regular intervals permit one to use a hook on the end of an iron rod or even a special spade for their removal. At the entrance to the factory brick arches are frequently built over the flumes. Under all circumstances the interior of the flumes should be accessible. The sheet-iron flumes have certain important advantages especially for the preliminary handling of beets—along the river front, for example. The wicker covers soon rot if left exposed for the entire year to the variations of the weather. Iron flumes may be attached to trestles, and thus overcome any obstruction offered by the environment. The arrangement is shown in Figs. 21 and 22. The sheet-iron flumes are mainly for temporary use when they are to be subsequently placed in other positions.

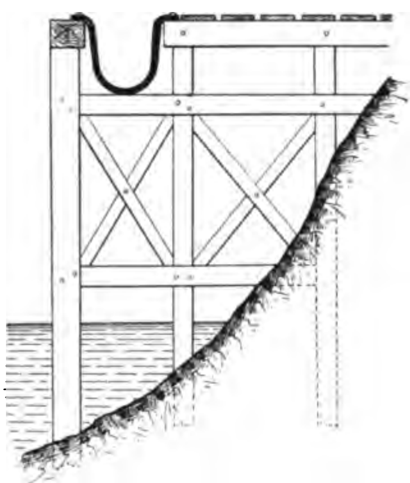


FIG. 21.—Sheet-iron Flume on Trestle.

**Transportable sluice.**—The transportable sluice of the CERYCH type consists of sheet-iron sections 3 meters in length, 50 cm. in height and 3 mm. in thickness, with an opening 32 cm. wide on top. At intervals of 6 meters small wheels are attached to these flumes, which are held in position by T irons sliding in grooves riveted on the hydraulic carriers. In the T irons there are holes by means of which the flumes may be raised or lowered so as to give them the

slant necessary under given circumstances (Fig. 23). Boards are placed on the ground, upon which the wheels readily run, and the

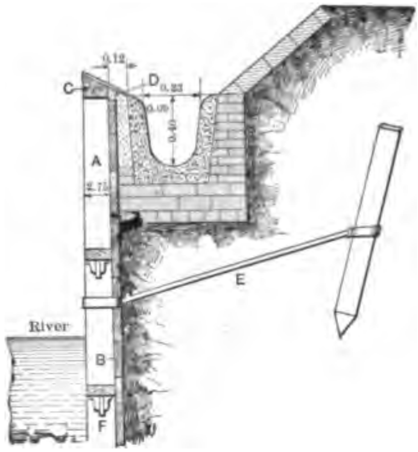
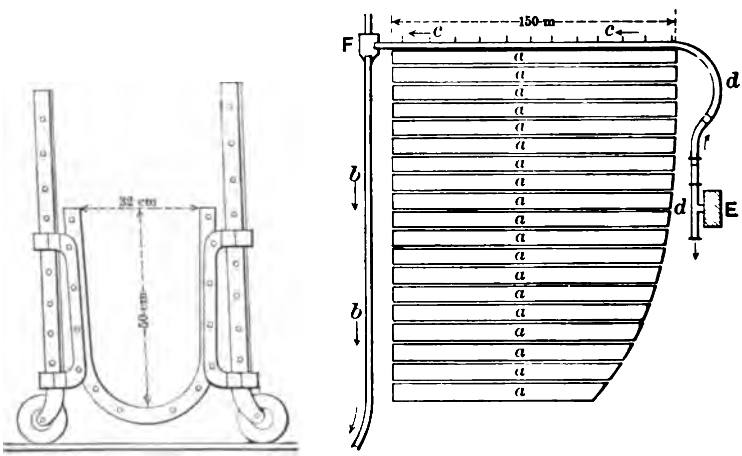



FIG. 22.—Sheet-iron Flume backed by Concrete and Brick.

entire flume may thus be displaced either in a direction perpendicular to its length, parallel to its length, or parallel to a fixed flume, *b* (Fig. 23), into which it empties itself through *F*. All the beet piles




Detail. General Plan of Silos.

FIG. 23.—CERYCH Transportable Flumes.

*a*, *a*, etc., are handled successively. The water is brought to the movable flume from the reservoir *E* by means of a hemp pipe, which at the Cernosic factory, Bohemia, has a length of 150 meters. The area of land covered with silos handled in this manner is

200×150 meters. In certain factories of Austria * the flumes have been mounted on a device resembling the DECAUVILLE cars, the tracks remaining covered with beets until the roots are needed at the factory. The economy of this method is self-evident. It is important to note that suitable rubber joints held together by bolts are between each section.

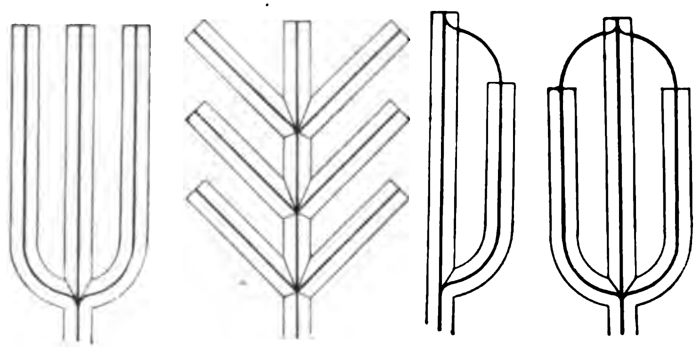
If the beets are exceptionally dirty through the neglect of the tiller, or have adhering leaves, etc., it becomes necessary to make allowances for this by increasing the slant and section of the canal and using more water, so as to flush out these foreign substances and force the beets to circulate.

Upon general principles, the slant given to these flumes is from 7 mm. to 10 mm. per meter, and when there is a curve, or a joint, or, in other words, in those portions of the hydraulic carrier where there is danger of an overflow, the slant must necessarily be increased by a few millimeters. Sometimes the slant is not sufficient, and when the canal is very long it should be increased so as to make allowance for the friction produced. If large volumes of water are available and in straight lines the slant may be reduced to 5 mm. per meter, under which conditions HOEPKE obtained satisfactory results. VON NIESSEN mentions other installations where the formation of the land demanded a slant of 30°, and, of course, in this case the beets fall directly into the water, otherwise they would be crushed. Under these circumstances very little water is needed in the carrier, in fact at such inclinations the beets would slide without water. A very rational mode has been suggested by DERVAUX † which certainly overcomes the difficulty. It consists in dividing the fall into several sections, permitting the beets to drop from one canal to another placed at a lower level. In some cases cited the beets had a fall of 2 meters. The main point in all these methods is to so arrange that the beets will not be bruised or crushed. On the other hand, when the slant is reasonable a simple hopper answers the purpose of communication between the two canals. A method of special interest that has been suggested is one permitting beets to be carried from one elevation to another by the use of a funicular run by hydraulic power. A car full of beets is brought up to a certain level by a car full of water on another track; but this mode requires enormous quantities of water. In Sweden the siphon plan has been used

* B. Z., **23**, 620, 1898–1899. † S. I., **24**, 563, 1884.

to carry beets under a railway track and has met with reasonable success. The open slanting sides in this case had a grade of 7 to 10 mm. per meter, the pipes of siphon were 40 to 50 cm. in diameter. SCHUPP * has met with some success by adopting a certain brick slanting combination in the yards of the factory, facilitating the fall of the beets into the canals.

**Flume organization.**—The suitability of such a flume organization in the yards of the factory depends upon the circumstances. Some of the arrangements adopted are shown in Fig. 24. In order



a b c d

FIG. 24.—Different Arrangements of Flumes connecting with a Central Feeder.

to render this mode of water distribution more complete the canals diverge from one point; the junction of the principal canal leading to the factory and the flumes is accomplished by a knee leading from the main sluice to the minor one, but this is not necessary if one flume is higher than the other. LALO † recommends that the intersections of the canals be placed at such intervals as to prevent the flumes from meeting at the same spot, and it is furthermore proposed to have very sharp angles at the intersection of the canals.

**Water in flumes.**—Generally the water used in a system of hydraulic transportation is that which has been previously employed for the condensation of the vapors of evaporation, either from the multiple effect or the vaccuum pan. If all this water can be used, one need have no apprehension that the supply will not be ample to meet every requirement of this mode. However, in certain beet-sugar factories the water must be repeatedly returned to the condensors after having undergone a preliminary cooling, in which case a certain amount must always be held in reserve

* D. Z. I., 7, 1087, 1882. † B. As., 9, 89, 1891–92.

for the flumes and washer. Upon leaving the washer the water is run into special decanting vats, where the mud, pieces of beets, etc., are deposited, and upon leaving this receptacle it may be again used, provided it is first raised to an elevation greater than the height of the canal. A scheme showing the cycle through which the water flows in the various cases that may present themselves is as follows:

**Condensor** —— **Decanting vats**

- Starting point of flumes
  - Natural flow
  - Pumps
- Leaving flumes toward decanting vats at end of canal
  - Natural flow to.............
  - Flow into reservoirs from where it is lifted by
    - Wheels with buckets
    - Chains
    - Centrifugal pumps
    - THIERY wheels
  - Entirely lifted to washer from there to
  - Partly lifted and then natural flow to
- Decanting vats
  - Taken up by
    - Natural flow
    - Pumps
  - Lost

The water from the condensors upon entering the flumes is generally at a temperature of 40° C., and this aids very much in the preliminary washing of the beets, particularly in winter when the earth adheres to the frozen roots.

**Quantity of water.**—Upon general principles, the quantity of water used depends upon the size of the canal and its inclination. If there is but a slight slant, more water is necessary to force the roots forward than when the inclination is increased, for in this case gravity aids the work to be accomplished. If there is only a small volume of water at one's disposal, then the most desirable width and slant to meet the emergency must be calculated. An excessively wide flume would mean considerable friction compared with the volume of circulating water used, and if the slant is zero there would practically be no limit to the volume of water necessary to float the beets. If the slant of the flumes was pushed to an absurd limit, it would be possible to slide the roots without any water. Some years since, when the entire question of hydraulic transportation was first discussed, it was pointed out that the excessive inclination of the flumes always necessitated the use of considerable water, while the reverse was actually true. MAGUIN * estimates that the volume of water needed for hydraulic transportation is about eight to ten times the weight of beets to be carried, the variations depending upon

* B. As., 9, 284, 1898–1899.

the dirt and impurities that must be handled. On the other hand, HEINZE * declares that the water consumption is inversely proportional to the square root of the inclination of the flume. In other words, if the water consumption is 8 times the weight of the beets for an inclination of 10 mm. per meter, for 15 mm. it would be

$$\frac{8\sqrt{10}}{\sqrt{15}} = 8 \cdot \frac{3.16}{3.87} = 6.5 \text{ times the weight of the beets.}$$

In all these arguments it must not be forgotten that if the water is excessively dirty the consumption will be increased to a very important degree. It frequently happens that the beets are so dirty that they cannot be floated. It is generally admitted that the volume of water circulating in the canal should be such as to float the beets at a height of from 11 to 13 cm., but on this question the experts do not agree. PAULY,† for example, declares that a 13 cm. elevation in the canal is not sufficient, on account of the frequent obstructions in the flumes. He recommends 25 cm. as the floating line, which height does away entirely with the complication in question. According to BOSSE,‡ the height of the water in the flumes, without making allowance for the space occupied by the beets, should be 11 cm. For an installation calculated on a basis of 5 mm. per meter at least 19 liters of water are needed per second; the velocity then is 0.76 meter per second. If the slant is 13 mm., 30.7 liters of water are required and a velocity rises to 1.23 meters per second. If, owing to existing grades, sufficient water cannot be had to meet the standard level of 11 cm., the general working of the flume will not meet expectations. The argument for the 11 cm. height of water in the sluices is that the water consumed would no longer be proportional to the increased velocity obtained by the circulating beets. By adopting a grade of 5 mm. per meter and a water level of 170 mm. the canals demand 40.45 liters of water, while the velocity of the moving roots would not exceed 0.988 meter per second.

**Water canalization.**—For this purpose iron pipes with lead joints between the sections are generally used. Iron pipes held together by various other arrangements have proved objectionable owing to the expansion due to difference of temperature between the exterior and the circulating water. No mode can

* C., **10**, 843, 1902. † Z., **32**, 924, 1882. ‡ D. Z. I., **6**, 455, 1881.

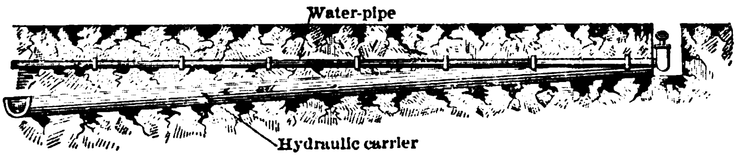



FIG. 25.—Section of Underground Flume with Water-pipe Distributor.

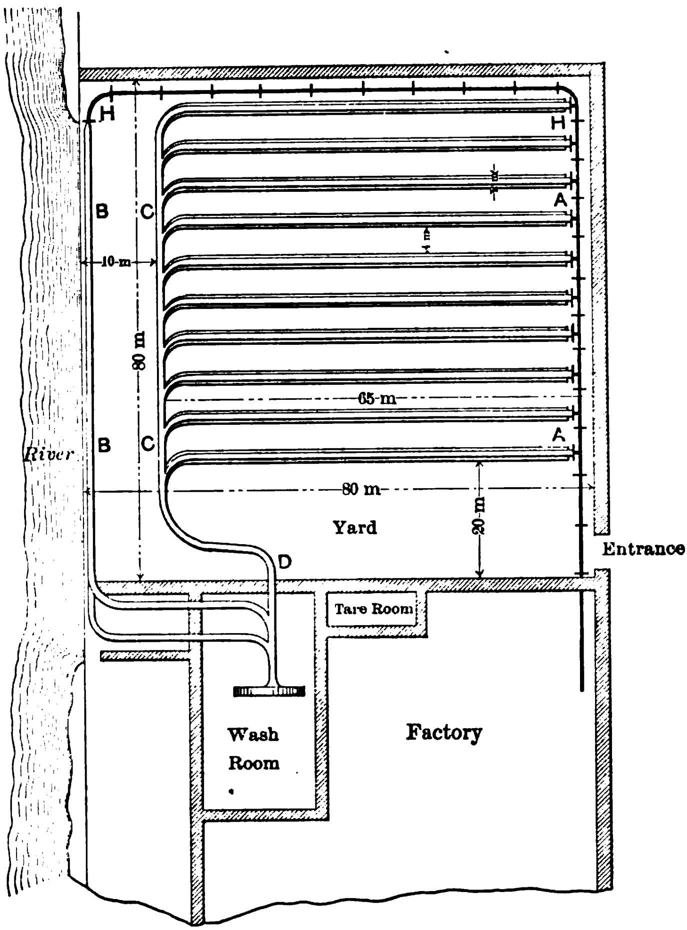



FIG. 26.—Plan showing a Series of Silos Built over Flumes with Water-pipe Connections.

be adopted more satisfactory in its working than the use of air-purging pipes of 50 mm. diameter placed at reasonable intervals, but mainly at the joints. No system is perfect without these purgers. These should rise to a level greater than the overflow of the condensor. The arrangement of the piping 50 cm. beneath the ground is shown in Fig. 25. The water pipes are generally horizontal, but in some cases they may be slightly slanted. The

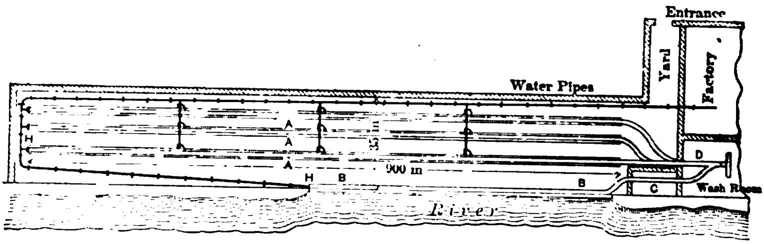



FIG. 27.—Very Long Silos with Water-pipe Connections.

valve at the point of junction is opened or closed as the case may be. The general arrangement of the pipes furnishing a series of silos along a river front is of exceptional interest. In Fig. 26 the silos are represented at *AA*, 50 to 60 meters in length; the flumes join at *D*, where they enter the factory, and *H* is the water-pipe distributor. In Fig. 27 a very long narrow yard is shown which

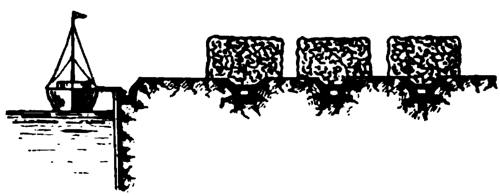


FIG. 28.

would demand flumes 200 meters in length, and special supply branches for the pipes, about every 50 meters. M. RONNEBERG places these water branches at the end of the silo which supplies the water to the flumes beneath. About 4 meters spacing is allowed between the silos, which, if possible, should be built parallel with the river front, facilitating the unloading. The cross-section, Fig. 28, shows the piles of beets over the flumes and also the flume placed in front of the water which conveys the beets directly to the factory.

Piping is not practical in some cases, as it is rather expensive, and furthermore, as the water contains considerable lime, there

would be a deposit which would soon result in an entire closing of the pipes; hence hot water is run from the condensors to the canals through open gutters. In order to prevent deposits in the pipes certain precautions are necessary, and a valve must be selected that offers the least possible resistance to water. In France preference appears to be given to a valve that is weighted down with a counterpoise of a very simple construction and working as rapidly as possible, one of the essentials being that the joint should be perfect even at low pressure. There is no better way to accomplish this than by the arrangement shown in Fig. 29. It

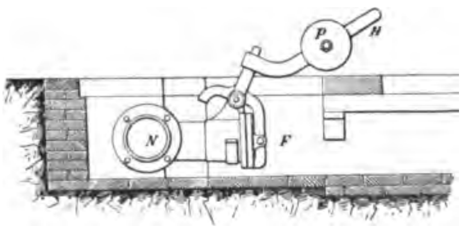



FIG. 29.—Counterpoise Valve.

is sufficient to raise or lower $H$ in order to open the communication between the water in pipe $N$ and the flume $F$. The valve is placed in position on a solid brick foundation. In order that the beets may float in the flumes under the best possible conditions the water should be received at a reasonable velocity and pressure. HEINZE * recommends an initial velocity of 2 to 2.5 meters per second upon entering the sluice, and the pipe connecting with the flumes should then have, for a plant slicing 300 tons per diem, a diameter of 125 to 150 mm.; for 600 tons, 225 to 250 mm.; for 1200 tons, 275 mm. The diameter of the pipe depends upon its length. Whenever possible the water in the pipes should circulate at a velocity of 1.5 mm. per second in order to prevent the possible incrustation of the interior.

**General working of the flumes.**—One of the most essential factors in the successful working of hydraulic carriers is a regular supply of water, especially if the grade is very slight and the volume of accessible water limited. The beets being piled up over the flumes to a height of 2 to 4 meters, they are tumbled into the flumes with a three-pronged hook or by means of a mattock when they are frozen into a compact mass. Generally the tendency is to fall too rapidly,

* C., **10**, 843, 1902.

and the person in charge must keep them back, otherwise there would be danger of completely clogging the flume and the object of the hydraulic carrier would be defeated. From this standpoint it is very important that the sluice should be accessible on all sides of its entire length for the purpose of preventing accidents. When the beets are thrown down into the flumes the covering of the sluices that had been removed during the filling should be replaced in position, the object being to allow the newly arrived beets to take the place of those sent to the factory. This procedure prevents accident that sometimes occurs; that is, the covers of the wicker type are floated on the surface of the circulating water to the washer or to the slanting lifting carriers.

In a hydraulic system of transportation, while the beets should be thrown in only at one place, they may be distributed at several places at the same time; there may be intervals, but the velocity of the water will not be the same, although this regulates itself after a time. Upon general principles it is not desirable to throw in at too many sections at once, yet the best results are obtained if the beets are swiftly thrown in one by one along the canal, for then the velocity of the water remains constant during its entire flow. The water flowing out at the other end should meet with no obstruction, and if it cannot escape as rapidly as desired, then some hydraulic lifting device should be used, which would in an emergency prevent an accumulation. When the circulation of the water is not continuous there necessarily follows an accumulation of stones, dirt and sand, and a considerable loss of time is occasioned before the carrier resumes its normal working.

When only a limited volume of water is accessible it becomes important to feed the hydraulic carrier at different points, but with regularity and slowly, so that no possible obstruction need be dreaded. In order to prevent an overflow of the canals when an obstruction exists, Bosse * proposes that special top gutters be placed at intervals. They should be 3 to 4 meters in length, and of a sectional area four times less than the flumes, their communication with the canals consisting of a sort of depression following the sluices. The water collected runs back into the flumes at a lower level than that of the obstructed portion. The most satisfactory condition is a continuous supply of water to the flumes which supposes no interruption—a condition not practically

* D. Z. I., 6, 455, 1881.

realizable, as in most cases the supply of beets is very much greater than the factory can possibly consume and a stoppage is necessitated. The workmen in charge should be kept informed as to what the conditions are, so as to prevent an abnormal accumulation of beets in the washer, which would necessarily cause a general obstruction along the entire length of the hydraulic carrier. The best plan is to keep the washer only reasonably full, so that the flumes may be entirely emptied after the signal of alarm has been given. At the point of intersection of the washer and the flume there should be placed a suitable iron grating to hold back the roots when the washer is full.

**Stone separators.**—It must not be forgotten that the water in the flumes not only carries the beets, but also all the dirt, etc., from the roots, and if not separated these will be carried into the washer and might continue their journey up to the beet slicer, where they would damage the slicing blades. In cases where the grade of the flumes is less than practical experience has determined, sluices soon fill with stones and dirt and the water carrier can no longer float the beets. In countries where the nature of the soil causes it to adhere to the roots, stone catchers may be arranged at suitable intervals in the flumes by simply digging out spaces in which the stones, etc., collect. These may be emptied by opening suitable iron valves communicating with the ground and with the decanting vats.

By the SAMMTLEBEN * mode iron baskets are placed in excavations made in the flumes, and beneath them is a perforated pipe that conducts water under pressure. The stones remain in the baskets while the beets are raised by the water and are carried in the direction of the washer. MAY † builds depressions with slanting bottoms in the flumes at levels somewhat lower than the sluices. Stones, being heavier than the beets, fall into pockets of perforated iron, through which water circulates under considerable pressure, thus necessarily raising the beets from their position. The extremity of the pockets is closed by a large iron grating through which the smaller stones may pass and behind which is a valve permitting the rapid exit of the deposit that is forced out by the escaping water.

The BEROUNSKY ‡ stone separator for flumes (Fig. 30) consists of a movable grating placed below the lower level of the

* N. Z., **39**, 122, 1897. † Z., **53**, 98, 1903. ‡ Oe.-U. Z., **27**, 569, 1898.

sluice *A*. The stones remain on the grating and are thrown down by a swinging arrangement worked from *S*. A spiral placed in a slanting position with its lower extremity in a pit, *BB′*, beneath the grating, carries the stones to the upper level, where

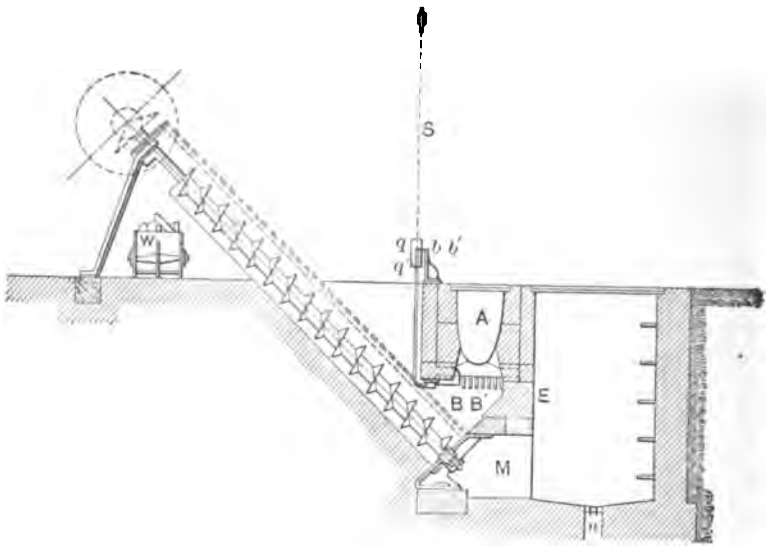



FIG. 30.—BEROUNSKY Stone Separator.

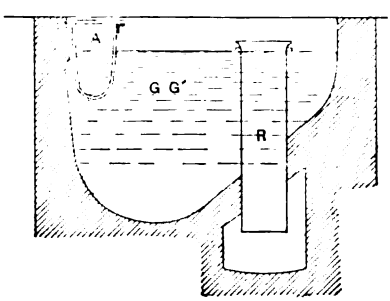
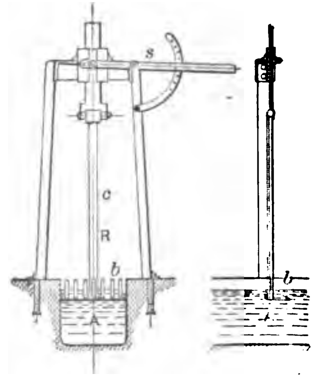



FIG. 31.—Sand Separator.




Front View. Side View.
FIG. 32.—Straw Arrestor.

they fall into a cart *W*. For sand separation (Fig. 31) it is sufficient to place a long lattice arrangement at the bottom of the flume and beneath it the pits *GC′*. The sand which collects in time may be removed by hand. *R* is an overflow.

At the end of the campaign farmers frequently keep beets under straw. The roots reach the factory with bits of the covering clinging to them. In order to stop these in the flumes, PASSCHEN makes use of a movable fork which may be raised or lowered by moving the lever *S*, communicating with *R*, as shown in Fig. 32. There is a free motion around *f*, so that the arrestor offers very little resistance. As the straws float near the surface *R* the forks should be only an inch or so beneath the water level. Another arrangement for this purpose has been suggested by GUTHERZ.* It consists of a small rake with movable hooks in which collect all the floating substances, such as leaves, straw, etc.

A similar idea is the use of a grating suspended in the water in the direction of the current, closely followed by another grating, but reversed and submerged in the water; the position of the arrestor in question may be regulated according to the depth of the water. When the particles in suspension reach a certain volume it should be removed.

**Opposition to hydraulic transportation.**—Objections to the hydraulic method for sugar-beet transportation from silo to factory were at first offered on the ground that the water consumption would be excessive and that there would be important sugar losses. As early as 1881 VIBRANS † called attention to the fact that this system would give satisfactory results even if water was available only in very limited quantities, as it could be filtered through the soil and used over again. However, in such special cases the most satisfactory mode consists in allowing the dirty water to run into the settling tank, their contents are decanted and frequently cleaned, using the same water almost indefinitely. Viewed in this light the volume of water is not a very serious question. This subject will be discussed in detail under the caption Decanting Tanks.

The skin of a beet that has not been bruised or mutilated offers great resistance, which would not ordinarily allow water to dissolve sugar in the interior cells; but the tapping of the beet opens these cells and in a measure permits the saccharine fluid to escape. However, under ordinary circumstances these losses are comparatively small.

For 100 parts of beets passing through a system of hydraulic

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* B. Z., 27, 207, 1903.
† D. Z. I., 6, 319, 1891.

transportation for a distance of 220 meters, the following sugar losses are considered a reasonable average:

With healthy beets and hot water (40 to 45° C.), 0.02 to 0.03 per cent loss of sugar as an average and 0.05 per cent as a maximum; with frozen and bruised beets, also in warm water, 0.1 to 0.57 per cent loss. Thus it is seen that under normal conditions the sugar losses are very small and may be reduced still further by having the canal as short as possible and by using cooler water. But with frozen beets the losses are considerable, and it is next to impossible to overcome the difficulty, especially where there are several roots frozen together with dirt between, as these cannot be floated with cold water, but, on the contrary, require water as hot as possible to thaw and remove the frozen earth before they will float. Upon general principles it may be admitted that the use of moderately cool water for hydraulic transportation would be of no advantage for either normal or frozen beets.

Recent special studies by PELLET show that when considering a distance from silos to factory of about 220 meters, the length of time the beets remain in the water before entering the washer being very short, the sugar loss must necessarily be insignificant, and even by the most delicate methods of estimation there is only a trace. The time required for beets to travel through a washer is very much greater than the time they remain in the carrier itself, and it may vary from seven to twenty minutes. In recent experiments an average of twelve minutes was allowed, to which were added three minutes required for hydraulic transportation. The sugar loss of beets during the period they are submerged is estimated at 0.02 to 0.035 per cent, though with frozen beets it is very much greater. On the other hand, the experiments of LOISINGER* show that these losses for normal beets, in flumes 60 meters in length, are seldom more than 0.08 to 0.1 per cent of the weight of the beet. The use of cold water reduces this loss by one-half, but with frozen beets that thaw in the hydraulic carrier the losses may attain considerable proportions.

During the period that the beets remain in the water, either before or during their washing and cleaning, they absorb a certain amount and will consequently increase in weight, this being especially true of wilted beets. The increase is generally not more than 0.5 to 1 per cent.

* Oe.-U. Z., **27**, 158, 1898.

## CHAPTER IV.

### BEET-WASHING.

**Beet-washing.**—After the beets have been floated in the flumes to the factory they are not sufficiently clean to undergo the first operation of sugar extraction, and an additional and very thorough washing is necessary to remove, first, the adhering earth; second, the small adhering roots, etc., and third, all foreign substances, such as stones, pieces of wood, straw, etc. After washing the beets must be thoroughly dried as far as this may be possible. To accomplish these requisites the roots must pass through several operations, as explained in the following outline:

| *Washing.* | | | *Draining.* | *Removal of small roots and drying.* | | |
|---|---|---|---|---|---|---|
| Beet washer | Spiral or bucket and band lift | Rinser | Spiral lift with perforated trough, perforated drum or shaker | Perforated drum, shaker, or brusher | Horizontal or inclined carrier | Endless band or bucket lift |

The operation of washing in its several phases has undergone many modifications during the development of the art of beet-sugar manufacture. As the mode of hydraulic transportation is of comparatively recent date, its introduction necessitated certain changes in existing plants. This fact explains why the hydraulic carrier in many cases does not terminate at the washer. At the factory termination of the flumes three conditions may present themselves: first, the water may be at once separated from the beets; second, water and beets may be lifted together and emptied into the washer; third, water and beets may be lifted together to a certain elevation and the water drained off before reaching the washer. When the water from the hydraulic carrier is to be used over again it is sometimes decanted and pumped into reservoirs at a higher elevation, otherwise it runs into the flumes by a natural flow without using a pump.

The operation of raising the beets from the hydraulic carrier into the washer is explained by the following scheme:

- Arrival of the beets and water by flumes
  - Water is separated either by
    - Knauer apparatus or stone separator, or
    - Lifting wheel with perforated buckets
  - Beets are lifted either by
    - Lifting wheel with perforated buckets on bucket bands
    - Spiral
  - Beets and water are lifted together by spiral
  - Water is separated at a certain height, the beets continue without water. This is accomplished either by
    - Wheels with buckets, or
    - Spiral with perforated portions after a certain height

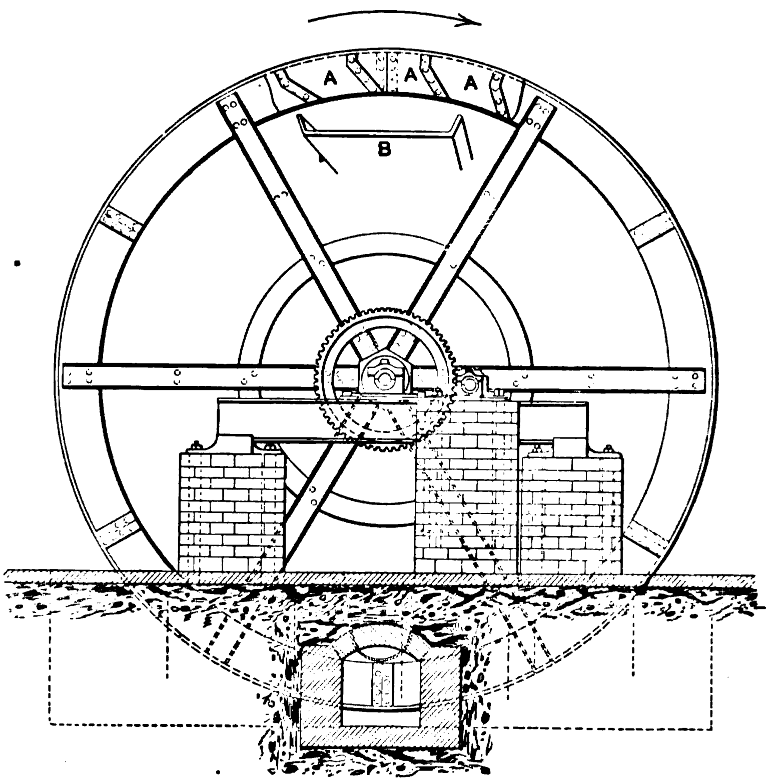


Fig. 33.—Iron Beet-lifter to carry the Roots from Flume to Washer.

As a general thing, the flumes are much lower than the washer, hence the necessity for the foregoing manipulations. When the washer is sufficiently high for the water to flow into the decanting

vats, a water and beet separator is used, the water going to the vats and the beets to the lift connected with the washer. The object of separating the water from the beets during the lifting is to prevent the enormous volume of water being handled from overflowing the washer.

**Lifting wheels.**—When there is a considerable difference between the level of the washer and the level of the flume lifting wheels are more desirable than spirals, the latter giving satisfaction only for a difference of 2 meters in the elevation, while the wheels still accomplish the work in a very satisfactory manner even at 6 or 7 meters.

In the RASSMUS * lifting wheel the generatrices are open and form troughs or buckets in very much the same manner as in water wheels. These buckets are made of perforated sheet iron, which permits the dirty water to escape, leaving the beets only to be handled. These are lifted and thrown into a vertical carrier or into the beet washer. The sheet- and cast-iron lifting wheel shown in Fig. 33 is very simple in construction. It is supported on an iron girder and is moved by means of suitable gearings. The beets are gathered from the flumes below and remain in the divisions *A* until they reach the top, when they fall into a slanting distributor, or hopper, *B*. Most of the modern lifting wheels now in use are based upon very much the same principle. A hopper is placed at the point where the beets leave the lifting wheel, and in this manner the roots slide down into the washer, being in nowise bruised or mutilated. It is important to note that in cases where the beets and water are to be lifted together the buckets are not perforated. In such cases most of the water runs out upon a perforated sheet iron curved in the direction of the wheel and falls into a trough which directs it to the decanting vats.

**Spirals.**—The outer cylinder in which the spiral lifting device is placed consists of sheet iron and has a considerable diameter, though in some cases preference is given to cast iron. The appliance generally has an inclination of 45°. When the beets and water are to be lifted only to a certain height and the water then separated, the cylinder forming the casing is perforated at that point. The cast-iron axis has spiral flanges to which is screwed the spiral itself, and a suitable bearing at top and bottom

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* N. Z., **11**, 213, 1883.

facilitates the rotation. The end pivot being much exposed soon wears out, owing to the considerable pressure to which it is subjected, and also to the wearing influence of particles of gravel, etc., that find their way into the interior of the bearings; but this difficulty may be overcome in a measure by the continuous use of a lubricant. The spacing between the sheet-iron spirals is somewhat less than the diameter of the outer slanting cylinder or casing. An arrangement of this kind is shown in Fig. 34. The beets are received through the flume *D*, both the water and the beets being raised to *E*, when the water is drained off through *E* and falls into the trough *C*, while the beets continue their upward motion and fall into the washer *B*.

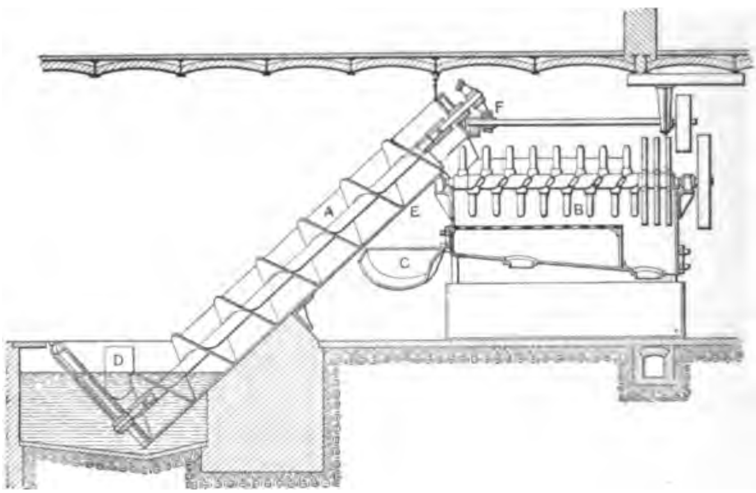


FIG. 34.—Spiral Beet Lifter between Flume and Washer.

The motion is given to the spiral lift by the conical gearing *F*. The maximum efficiency of this appliance can be obtained only when no stones or gravel get between the cylinder and the spiral, and this shows the importance of keeping the space in question as small as possible. Do what one may, there is always a certain wear and tear on the outer periphery of the spiral to which a narrow band of iron may be screwed, that can be renewed after each campaign. It may be said, however, that the larger lifting spirals with cast-iron outer casings are very strongly constructed in order to crush the small stones, etc., that may obstruct or resist the rotatory motion.

of the device. The clogging generally occurs at the bottom portion of the spiral, at a point where the hydraulic carrier empties into the pit, into which the spiral lifter is plunged. Owing to this arrangement a considerable number of stones necessarily collect, which, if not removed, stop the spiral and frequently bring about considerable damage to the outer casing.

In the MURKE * spiral used in the beet washers the portion coming in contact with the hydraulic distributor is somewhat smaller than the upper part, so that the space between the spiral and the outer sheet-iron covering is sufficiently large to prevent clogging and to allow stones, dirt, etc., to escape and fall by gravity. If, notwithstanding this precautionary measure, the stones are carried forward and form wedges, the spiral goes out of gear and frees itself. The axis of the helice rests above on a transverse pivot bearing, and at the other end there is another bearing with concentric sliding attachments. The freeing of the helice in an emergency is accomplished by simply pulling a chain by which the lower part of the axis is raised, when all the beets and stones fall into the hopper below, to be subsequently carried upward by the revolving spiral carrier. The lifting spirals as now constructed receive their motion from suitable gearing, and in order that the motion shall be softer and easier one of the cog wheels has wooden teeth, which break when an accident occurs through the abnormal resistance caused by the obstructions before mentioned, and may be readily and rapidly removed. If the beets being handled have been cultivated on soil of a gravelly texture such accidents are of frequent occurrence, and advantage may be found in having in reserve one of the conical wooden-teeth gear wheels, as they may be placed in position in a few minutes. The spiral should revolve at a velocity of from 40 to 60 revolutions per minute, depending upon the size of the apparatus, the smaller types moving more rapidly than the larger ones. In special emergencies the velocity is increased, which, while it also increases the efficiency, is not to be recommended, for the chances of accident are greater.

**Separators.**—The KNAUER separator shown in Fig. 35 consists of a drum $D$, the bottom of which is formed by a grating, the beets reaching their destination through one or several flumes, $B$, $C$, etc.,

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* Z., 50, 461, 1900.

connecting with the drum separator, in the bottom of which, opposite to the place where the beets enter, there is a hole *M* that allows the beets to fall upon the lifting device. The water running through the grating has a natural flow through a canal into the decanting vats. For the purpose of pushing the beets into the hole there is a vertical shaft *H* with three arms, which has bottom brush attachments, by the revolution of which the bottom grating

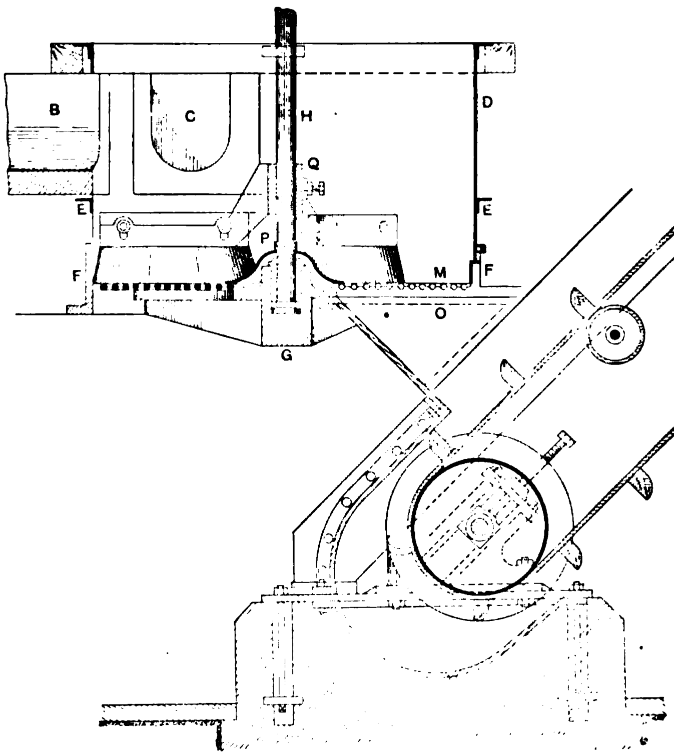



FIG. 35.—KNAUER Beet and Water Separator.

is kept thoroughly clean. In this case there is used a band and bucket carrier, the arrangement of which is clearly shown in Fig. 35.

**Beet washers.**—These appliances are very numerous, but the ones most used are of two types, those with arms and those with drums. The first mentioned has a perforated double bottom, in which the arm agitators revolve, while the drum type has a perfo-

rated horizontal cylinder revolving in a trough filled with water. The beets run through the drum and rub one against the other, thereby becoming moderately clean. The perforated-drum types of washers have of late years become obsolete in Continental Europe. Sometimes, as in the HAEHNE * washer, transverse divisions are used, which take up more or less space, their object being to retard the motion of the beets, which in these conical washers advance too rapidly. Of late years preference seems to be given to long washers with arm agitators and large stone separators. The washers with revolving drums have become obsolete on account of their limited efficiency; and while some advocate vertical washers, which it is claimed can completely separate the stones, straw, leaves, etc., they have been in use for too limited a period to pronounce positively upon their value.

As the beets have had most of their impurities removed during hydraulic transportation, the rôle of these washers is secondary as compared with its former importance. It must not be forgotten, however, that the operation renders excellent service in removing particles of stones, etc., that would destroy the edge of the blades in the slicer, resulting in irregular cossettes and poor working of the diffusion battery.

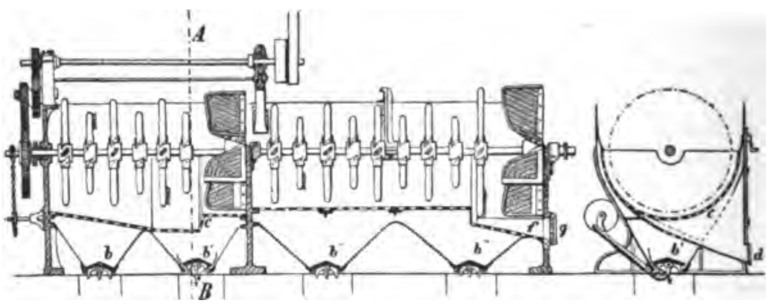
The first beet washer of the arm-agitating type which met with any practical success was that of LEINHAUS † and HÜLSENBERG, used over twenty years ago. From that time on these appliances were made of larger dimensions until they were able to meet the demands of modern sugar plants. At present the power needed for their working is proportionately less than formerly, while the work done is much more thorough and there is less water used per ton of beets washed.

As has been previously explained, the washing operation includes a preliminary washing followed by a second one. Generally two appliances are now used, one after the other, to thoroughly accomplish the washing. In most cases two arm agitating washers are employed, in the first of which most of the adhering earth is separated, while in the second the operation is continued with cleaner water. In the GOUVION ‡ combination the second washer is placed at a level slightly higher than the first, and the roots are raised to it by means of a spiral, water being sprayed into this device in order

* N. Z., 7, 117, 1881. † N. Z., 7, 259, 1881.
‡ B. As., 14 to 16 Annexes VIII, 1893–1894.

to rinse the roots during their passage. It is better to place the second washer below the first so that the beets will fall by gravity after the first operation, thus eliminating the lifting apparatus, an inclined hopper slanting at 45° connecting the two washers.

To prevent the beets floating on the surface of the water during the washing, BERGREEN * subdivides the washer into several sections, each having suitable arm agitators with a flattened surface, which, at the proper moment, raise the beets and project them into the water of the next compartment. In this combination several appliances are united in one; each, however, is absolutely separated from the others and the water in each has a progressive cleansing effect. This idea is now very widely adopted in Germany, while in Austria the WIESNER † washer (Fig. 36) is very generally




Side View. End View.

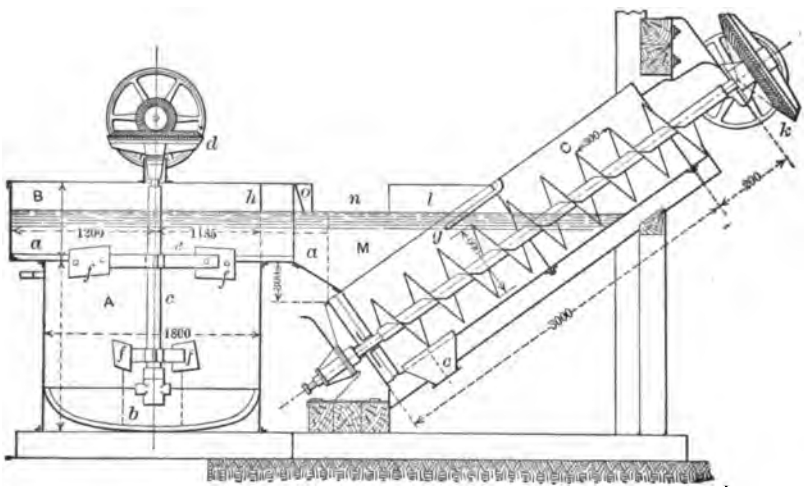
FIG. 36.—Austrian Beet Washer.

used. This consists of a large vat divided into two sections, one of which is used for the first and the other for the second washing. Upon the main shaft are the arm agitators forming a spiral, and at the end of each compartment is a rotating basket attachment which projects the roots after the operation, first, into the second section, and then out upon the beet carrier at the other extremity. Underneath the sheet-iron perforated bottom is a series of pockets with large emptying valves $b$, $b'$, $b''$, $b'''$.

In Hungary the HENNEZEL and FRICOURT types are much used. The apparatus is very long and the washing and rinsing are all done in one operation. The beets move slowly, and the clean water towards the extreme end finally removes all remaining impurities.

* N. Z., **12**, 8, 1884. † B. Z., **14**, 143, 1889–1890.

It is interesting to call attention to the RAUDE * beet washer (Fig. 37), especially constructed for very dirty beets and such as are mixed with gravel and dirt. In this washer the cylinder, *A*, is placed in a vertical position, the bottom, *b*, is oval, and the agitators are upon a vertical shaft, *c*, receiving its motion from the gearing, *d*, the agitators being thus set in motion. The dirty beets, as far as possible, reach the centre of this apparatus, the shaft of which revolves at a velocity of 18 to 20 revolutions per minute. The tendency of the beets, owing to gravity, is to fall directly to




Side Sectional View.

FIG. 37.—RAUDE Beet Washer.

the bottom, but the centrifugal action of the arms and their flat endings cause the beets to move downward on a slant, while the stones that are heavier fall vertically without coming under the influence of the agitators. At the bottom of the washer are small agitators, *f*, inclined at an angle of 73°, which strike the beets and force them upward, during which period there is considerable friction between the beets. From the upper and wider portion, *B*, of the washer they escape through an opening, *a*, and slide down upon a spiral carrier, *C*. The opening in question may be so regu-

* D. Z. I., **21**, 2229, 1896.

lated as to control the number of escaping beets and may be entirely closed by a movable grating, so that only water will escape. This washer should always be filled with water to the upper level, so that the stone-separating action may be very thorough in every respect. After the stones have collected on the slanting bottom of *A* they may be removed through suitable doors, and this cleaning out should be carefully done so as not to touch the small agitators at the bottom. As this washer communicates directly with the hydraulic carrier, there is an overflow, *n*, in the basin *B* through which all the water runs off, at the same time floating out bits of straw, wood, etc. This washer is very generally used in Russia, and although it is apparently rather complicated, demands very little power for its working.

The agitating arms of beet washers are generally made of wood, and are either screwed on or held in position by a pivot passing through a sleeve that forms part of the iron casting of the revolving shaft. These arms may be rapidly replaced in case of an accident caused by some obstacle offering great resistance, and it is therefore of advantage to have several of these movable arms ready for an emergency. In some types of washers the arms are of cast iron and have a hollow neck corresponding to the diameter of the shaft, upon which they are attached in pairs held together by suitable bolts. The bolts should be only reasonably tight, so that if any resistance is offered they will simply remain against the obstruction while the shaft will continue its motion under the friction of the sleeve with a reciprocally lesser velocity. The advantage of this is self-evident: the arms are not broken and when the stones have been removed the bolts are tightened and the work continues as before. In the HENNEZEL * washer the moving shaft has sleeves upon which the arms are attached which may be rapidly changed in case of an accident. With the exception of the last two these sleeves are all movable and have teeth-like sides permitting one section to fit into the other and thus forming collectively a complete whole that is made to revolve through the action of the fixed sleeve. In most of the modern washers these sleeves are in two sections bolted on the shaft. Some types have comparatively thin agitating arms and almost touch the perforated bottom of the washer. They have sections that vary from one end to the other of the washer, depending upon the work they

* N. Z., **13**, 135, 1884.

are to accomplish in forcing the beet to circulate during the washing operation. In order to prevent any possible clogging between the arms and the bottom of the washer their centre of rotation is not exactly the same as that of the revolving shaft, and they thus get further and further away from the outer surface of the washer as they rotate upwards. The bearings of the shaft, which frequently offer difficulties, in the early machines were made of pear wood, but in most cases coming under the writer's notice they are of metal. Excellent results have been obtained by conducting the water under pressure from the diffusion tanks by means of a small

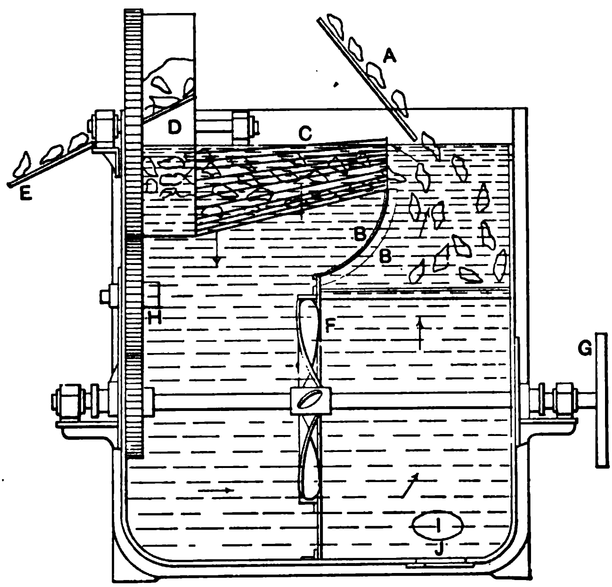



FIG. 38.—LOZE Stone Separator.

pipe into the oil box, under which conditions the bearings will last for years without requiring renewals.

The driving gear of beet washers consists generally of cog wheels so as to obtain a regular rotary motion and an easy starting when the apparatus is very full of beets. The number of revolutions in a given time depends upon the size of the washer and the amount of work, but it varies from six to thirty per minute.

Washers of recent design, such as the MAGUIN type, demand

sometimes considerable power for their working. Their length varies from 2 to 3 meters. It is estimated that when slicing 100 tons of beets per diem the length should be 2.5 meters and the width 0.90 meter, demanding 4 H.P. for its working, while for a 300-ton plant the washer should be 3 meters in length, 1.1 meters wide and have 5 H.P. for its working.

**Stone separators.**—Upon leaving the washers beets are frequently mixed with stones that may have been thrown into the flumes with the beets, and while the types of washers described in the foregoing have pockets and devices for collecting the stones, experience shows that stone separators are an important adjunct to the washer. In the ZWEIGART * apparatus the beets are thrown into a hopper full of water, from which they are forced into the washer or to the beet elevator, using water under pressure for the purpose. The heavier stones remain and fall to the bottom of the receptacle, from which they are removed through a manhole. The LOZE stone separator (Fig. 38) consists of two compartments between which a screw, *F*, revolves. The agitation is sufficient to raise the beets, but at the same time it allows the stones to fall to the bottom and through the grating, *B*, the spaces between the bars of which are sufficiently wide to allow an easy passage of the stones. The beets fall from an inclined plane, *A*, into the water and are finally taken from a slanting grating, *C*, and lifted from the apparatus by a revolving drum, *D*. The movement of the screw *F* is given by the pulley *G*, and the upper perforated drum is also made to revolve through the train of gear-wheels *H*.

The MAGUIN stone separator has some special advantages. The general arrangement, however, is rather more complicated than the general type of this special appliance; it consists essentially of an upper and a lower part. The upper part is semi-cylindrical and of sheet iron, with a revolving shaft and suitable arms acting as agitators and forcing the beets to move forward. At one extremity there are two divisions which have at the bottom iron gratings, with a separation half way up. Below these is a novel arrangement consisting of a tube with a screw or propeller blades such as are used on steamers, revolving on a horizontal axis, and receiving its motion from a gearing, which connects also with the upper agitator. Water circulates freely, and its direction is governed by the rotation of the shaft.

* N. Z., **5**, 37, 1880; N. Z., **10**, 55, 1883.

The beets are thrown into one of the upper compartments, and sink at first owing to their fall; but water passes through the grating, and the stones, dirt, etc., fall below, the roots are carried over the separation and the last particles of earth fall through the grating, there to be subsequently removed from a suitable manhole placed at the bottom.

In certain cases it is found desirable to place a spiral-lifter stone separator after the washer. The CHARPENTIER-DEGROUX combination consists of a sheet-iron slanting spiral at an angle of 45°, the lower portion of which has been removed so as to diminish the wear and tear of the contact with stones which are deposited

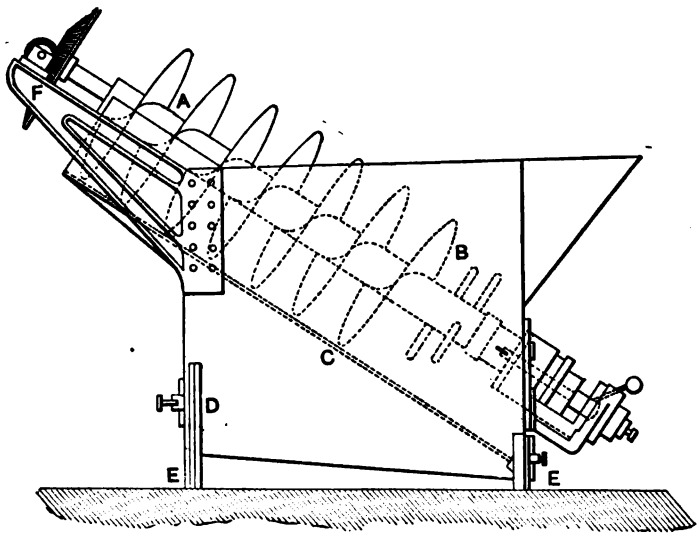



FIG. 39.—CHARPENTIER-DEGROUX Lifter and Stone Separator.

in the lower trough, and in order to prevent the accumulation of beets in that portion small projecting arms keep the roots in constant motion. The stones fall to the bottom and are removed at *E*, while the beets are raised to *A*, where they are thrown into another lift (Fig, 39).

In the stone separators of the HEINZE * design there is a sluice valve, closing from bottom to top. The advantage claimed for this mode is that if the valve is opened at certain intervals there is no danger of the stones stopping half way during their

* D. Z. I., **25**, 1204, 1900.

exit and thus permitting all the water of the washer to escape. However, it may happen that a beet may prevent the entire closing of the sluice, and to overcome this difficulty the valve has been furnished with a sharpened edge that simply cuts the root in two. As another precautionary measure to prevent too much water running off when the stones are being taken out, a second valve is placed behind the first, the opening limit of which varies with each special case.

**Cleansing of beet washers.**—The removal of dirt and water from beet washers is automatically accomplished by opening the bottom valves. If this operation is performed only intermittently there is always a certain deposit of dirt and particles of roots, and these should be taken out through the side manholes. Very satisfactory results have been accomplished by the use of the MICHE * spiral placed on the bottom trough of the washer; all the particles that have passed through the false perforated bottom are forced out and fall into a special depression of the apparatus, from which they may be subsequently removed. The spiral in question need work only when the necessity demands its action.

Among the earliest types of automatic cleaners for washers is the LEINHAUS † and HÜLZENBERG apparatus for the removal of dirty water and residuary deposits. At the lower part of the washer is a discharge pipe which may be opened by the simple working of a lever that receives its motion indirectly from the shaft of the washer. At every opening of the valve water rushes out and carries the deposits with it. This arrangement was objectionable, in that the volume of escaping water always remained about the same, while the requirements in practice demand that this quantity should be varied with the work to be accomplished.

The HENNEZEL combination overcomes the difficulty. This washer does not have a double bottom. At the extremity where the beets enter is an emptying pipe for the dirty water, which is closed and opened after each revolution of the shaft by the direct action of a cam; this arrangement permits a complete regulation of the volume of escaping water. In cases where the washer receives its water directly from the hydraulic carrier the pipes should always be of considerable diameter to allow for the overflow of water in excess. The MAGUIN washer has a small cylindrical

* N. Z., 7, 134, 1881.  † N. Z., 7, 259, 1881.

receptacle with a float which opens a valve that allows water to escape when the washer is too full. One objectionable feature of these cam regulating devices is that if the shaft of the washer should stop so that the cam points upwards the washer would soon be emptied.

Under ordinary circumstances the perforated iron bottoms of beet washers soon become clogged, owing to the broken tip ends of beets that force their way into the openings, and under these circumstances the efficiency of the apparatus is very much diminished. The roots then are poorly washed and the adhering dirt not escaping to the compartment beneath is carried further by the roots. BAKER and BETANY'S * system consists in having pipes beneath the perforated iron, through which is forced compressed air. The passages are thus always kept clear and deposits of any kind are no longer possible. The idea is not new, for QUASCHNING † had practically applied it some years before.

**Surveillance of the washer.**—In most factories visited by the writer the washers were not sufficiently looked after, and numerous complications followed in the various operations of sugar extraction. Under all circumstances the water should be renewed as often as possible. Frequently residuary water from the diffusion battery, that from the cossette presses, or the decanted water that had served for the hydraulic transportation is used in beet washers. However, when comparatively pure hot water is available the water already used should not circulate in the washer, as the sweet waters just mentioned frequently contain certain germs which would bring about many organic changes in the diffusion battery, and would result in impure juices. Under all circumstances experience shows that the beets had better first be cleaned with pure water after they leave the first washer.

When frozen beets ‡ are to be handled warm water is introduced into the washer, or steam may be injected under the perforated false bottom.

Upon general principles it may be said that beet washers should be placed in suitable closed premises rather than simply under an open shed, as the work is then more carefully watched. The floor of the wash room should be slightly slanting so that water cannot accumulate, and all sides of the washer should be accessible, hence the importance of ample room.

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* D. Z. I., **24**, 706, 1899. † D. Z. I., **26**, 591, 1901. ‡ STOHMAN, p. 89, 1899.

**Sugar losses.**—Unfortunately during the washing of beets important sugar losses necessarily occur through the same causes as are discussed under the caption of Hydraulic Transportation. JULHIARD * points out with reason that these losses vary with the temperature. The sugar losses as previously explained are very slight for healthy beets, but for frozen beets that remain in water at 28° C. for fifteen minutes, the loss may reach 0.38 per cent of the weight of the beet and 0.5 per cent in water at 42° C. GUIBAL'S † analysis shows a loss of 0.1 per cent during washing. BAUDRY ‡ places the loss after remaining in the washer ten minutes at 0.6 to 0.7 per cent. Another authority has proved that the water absorption by beets during fifteen minutes' washing may reach 0.6 to 0.9 per cent, depending upon the temperature. PELLET says that the water absorbed and adhering to beets varies from 0.8 to 1 per cent.

**Removal of residuary.**—Owing to the difficulties of raising dirty water, clean water should be used wherever possible. Upon general principles the dirty water from the hydraulic carriers and the washer should be carried off by some means as fast as it is obtained. It may flow from the washer directly to the decanting vats, but unfortunately the arrangement of most factories does not permit of the practical carrying out of this idea, and the fact is that in most cases the question of handling the residuary water is most difficult of solution. The lifting of the dirty water may be accomplished by several methods, among which may be mentioned, first, wheels with buckets or troughs; second, the THIERRY mode; third, chains with buckets; fourth, pumps, pistons, and centrifugals.

**Wheels with buckets** is a mode of lifting that has been in vogue for over twenty years.§ and it has been pointed out that centrifugals, pumping, and pulsometers gave very poor results. Fig. 40 shows a wheel of very simple construction, strongly built, no portion of which can get out of order or become clogged by radicles, etc., from the roots. The buckets *C* collect the water from the sluice *A*, which brings the dirty water from the washer or flumes and empties it into the canal *B*, in which it is carried to the decanting vats.

Several European beet-sugar factories have obtained excellent results with an elevator of the THIERRY ¶ type (Fig. 41). To raise

* B. As., **16**, 347, 1898–1899. † B. As., **15**, 204, 1897–1898.
‡ B. As., 8, 628, 1890–1891. § N. Z., **13**, 135, 1884. ¶ S. B., May **1892**.

4000 liters 10 meters high per minute 13 H.P. is needed, which efficiency is said to be greater than that of any known pump. The wheel makes 10 to 20 revolutions per minute. It consists mainly of one or more tubes, *O*, wound spirally around the drum *R*. The waste water to be raised enters at *S* and carries with it all the residuum from the appliances already mentioned. It leaves at the other end and passes through *T* into *V*, and there is forced upward, to be subsequently distributed upon the neighboring lands, where it does the least harm or may be advan-

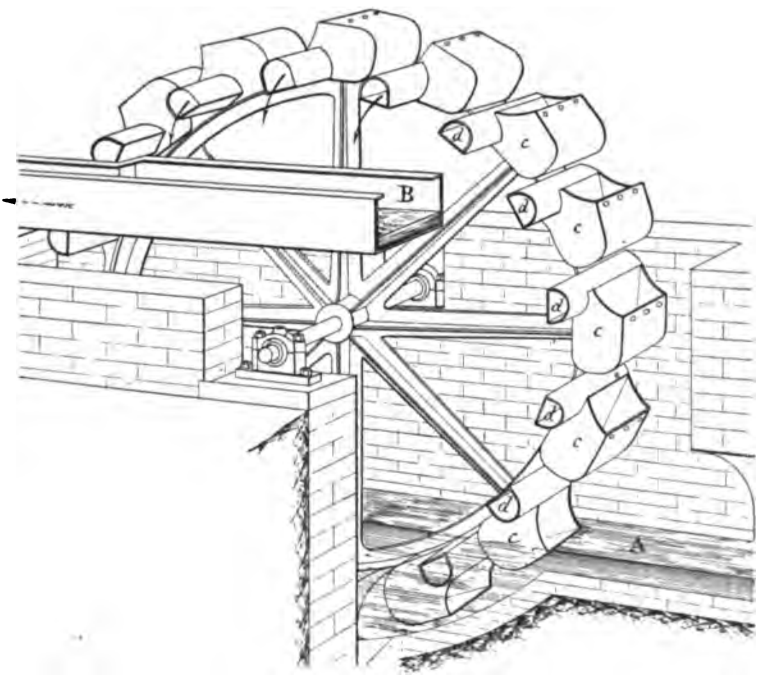
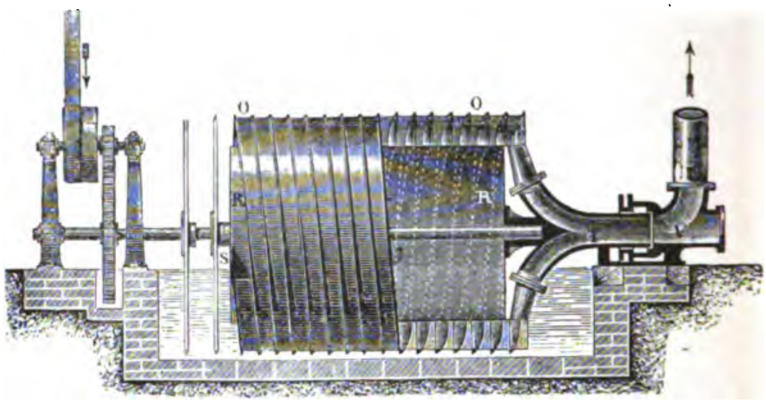


FIG. 40.—Wheel with Buckets for Dirty Water.

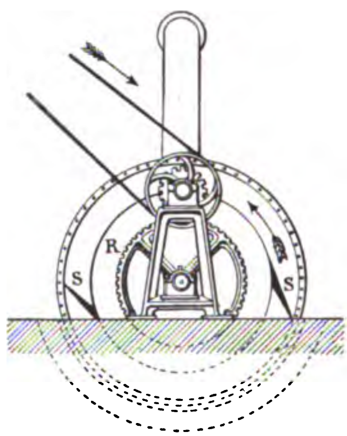
tageous. During our very cold winters it might be found necessary to increase the number of revolutions of the apparatus, thus obtaining a greater velocity of the moving liquid, or to protect the tubes by some non-conductor to prevent freezing of the water.

**Chains with buckets** have met with a certain success in special cases which have come under the writer's notice. The arrangement is very simple and need not be described. If, however, dirty water must be lifted to a considerable elevation these methods no longer answer the purpose if one is obliged to resort to pumps, either with

pistons of the centrifugal type or the ball combination. The regular pumps are the strongest, but the water must be well mixed before entering the cylinder in order to prevent clogging of the valves. The rubber ball valve pumps offer exceptional advantages,




Side View.




End View.
FIG. 41.—THIERRY Waste-water Lift.

for they can handle the water with all its impurities * provided the balls used are of sufficient diameter. VIÉVILLE † very justly points out that horizontal pumps should be rejected and preference given to the vertical plungers, which should have rounded extremi-

* B. As., 9, 82, 1891–1892. † La S. B., 22, 452, 1893–1894.

ties. To prevent the wear on the packing, it is desirable to surround the piston by a gutter portion in which clear water may be introduced, forming a perfectly tight joint around the piston guides. Experience appears to point to the advantage of using small pumps with short diameters rather than large ones. Upon general principles it is maintained that the centrifugal mode of pumping always necessitates 40 per cent more power than is needed for the piston devices.

**Centrifugal pumps.**—Notwithstanding their many disadvantages many beet-sugar factories continue to use centrifugal pumps. They take up very little room and may be placed almost anywhere that they are needed. One of their most objectionable features is that the suction tube readily becomes exhausted, and for that reason they should be placed at a low level. Under all circumstances these pumps should be of very simple construction so that they may be readily taken apart. When elevations of 25 meters are to be reached two pumps worked in conjunction should be used. When handling dirty water by these pumps several essentials must be borne in mind, among which may be mentioned the importance of separating the heavier and bulky impurities from the water. Whatever be the method adopted for raising such water it should undergo a preliminary straining to remove all the particles in suspension. The tip ends of roots thus separated may be subsequently utilized for cattle-feeding. In some factories this residuum is mixed with the cossettes during their pressing, but when the cossettes are to be subsequently siloed the plan is not to be recommended. The strainer used for these dirty waters is very long, with a space between the bars of 5 to 10 mm., and deposits are now and then removed from their surface. Another device having the same object in view was introduced by HEIKE * some years since. In this the residuary waters are run over a horizontal drum with slats on its outer periphery, the sections of which are so arranged that the spacing between them increases as they approach the interior of the drum. The deposits are held back and removed with special scrapers, and the drum never clogs owing to the special arrangement of the spacing. To retain tip ends of beets in suspension in the residuary water from the washer KARGES and HAMMER † use a strainer consisting of a circular revolving perforated disk, and the filtering surface is kept clean

* Z., **52**, 565, 1902. † Z., **50**, 853, 1900.

by means of suitable scrapers. As it is shallow it may render excellent services where there is only a slight difference in levels for the fall of the circulating water. In the THOMAS method (Fig. 42) the dirty water arriving through the sluice is first strained upon an inclined plane, the residuum slides along the slant and is carried upwards by a suitable lift, *K*, and the cistern is thus constantly kept free of all deposits. The dirty water passes through the sieve, falls upon an agitator, *J*, which prevents any deposits, is

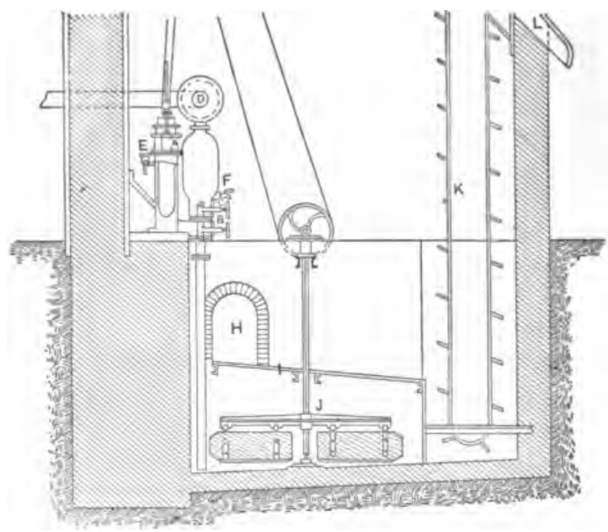



FIG. 42.—THOMAS Dirty-water Pump Lift and Strainer.

then raised by a pump, *L*, with a suitable vertical plunger and forced into the pipe connecting with the decanting vats.

**Decanting vats.**—The waste water from the washer is sent to the decanting vats in which the final impurities, such as earth, are deposited. These include those substances that the previous straining devices have not sufficiently separated. In some special cases it is customary to send all the residuary water to these decanting tanks, but in so doing it is apparently forgotten that the decanting of residuary water, taken as a whole, has many important phases that must be considered separately and collectively, and is a problem capable of many solutions. The residuary water from the flumes and washer, which holds important organic matter in suspension, is of first importance. Among the first suggestions

was that of allowing the deposits to be made in shallow tanks of enormous proportions, but this idea had many objectionable features; for example, BODENBENDER* rightly points out that rapid fermentation would follow, involving the formation of lactic and butyric acid, which always carries with it a detestable odor. On the other hand, RASSMUS overcame this difficulty by using several decanting vats, covering only a limited number of square meters and comparatively shallow, which were emptied as soon as full. This mode is the one in vogue even up to the present day. The decanting vats of the standard type cover reasonable area and are generally made of well-cemented brick or stone. Their depth is about 1.5 meters, and beyond that limit they would be difficult to empty, though their size is regulated by the nature of the soil handled as well as by the working capacity of the beet-sugar factory with which they are connected. They should be larger for claylike deposits than for sand. In the large receptacles the water has less circulation and the deposit is greater. However, in order to overcome the question of the stagnation of deposits and their ultimate putrefaction it is found desirable to reduce the size of the vats, increase their number, and to empty them more frequently. Under the best possible conditions they should be emptied weekly and be of square shape. They are placed one after the other with a common distributing trough on one side and a common exit trough for the decanted water on the other. In the first tank the heavier impurities are deposited and the water continues its journey, passing from tank to tank. After five have been passed only comparatively few particles remain in suspension. Among the best of all the decanting methods that have been suggested may be mentioned the FOELSCHE system (Fig. 43), which consists of a polygonal structure divided into triangular divisions where the particles in suspension are deposited. One canal extends entirely around the compartments, passing at first around the centre and then extending to the outer periphery of the polygon. By suitable sluice valves any compartment may be placed in connection. The water once decanted leaves the exterior canal to find its way into the flumes of the hydraulic carrier. When one of the sections is full of mud, etc., it is isolated from the series and is then placed in communication with the central circular section by opening the sluice lock, or

* Z, 33, 965, 1883.

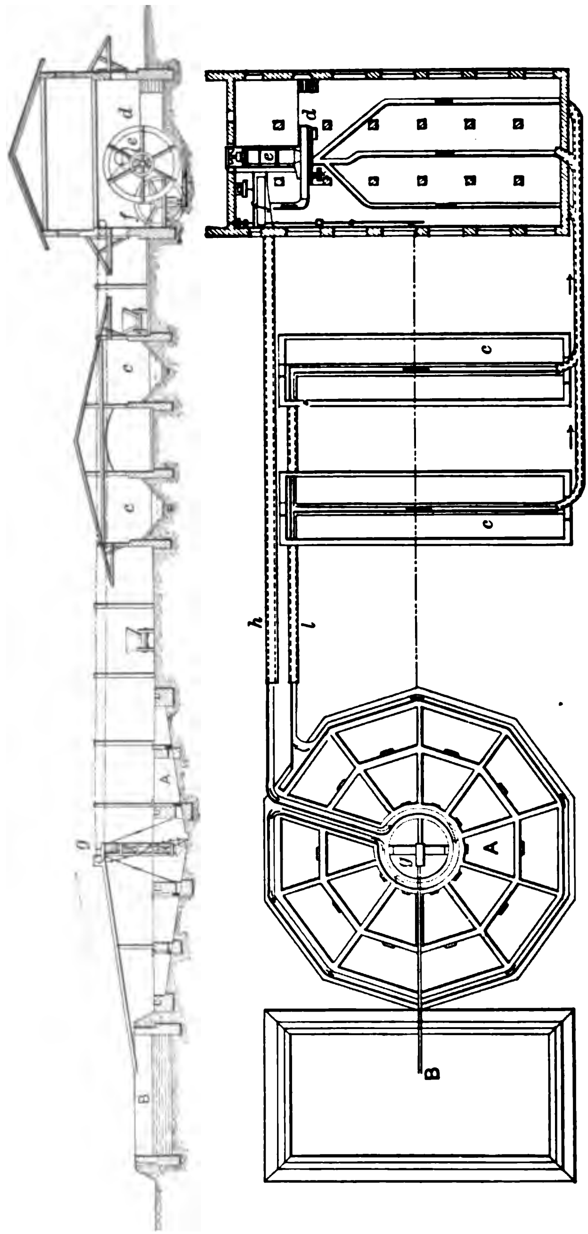



FIG. 43.—FOELSCHE Decanting Vat Combination.

valve. In the central section is a bucket drag, which removes the deposits and empties them into a slanting wooden trough, upon which they slide into *B*, a cistern of considerable size. There they remain until the summer, when they are removed. The decanted water returns through *l* to the hydraulic carriers, passing under the silos *C* and carrying the beets in the direction of the washer *e*, where a lifting wheel, *d*, raises both the beets and the water. The dirty water running off from the washer is again lifted by *f* and flows through *h*, as shown by arrows in the figure and finds its way into the compartments *A* previously men tioned.

As soon as one of the compartments has become full of mud and deposits, and has been isolated from the others, the water that is distributed is sent into the next compartment of the series. As a general thing these tanks are emptied by hand, for which purpose boards are placed upon the mud, which becomes more or less compact and is sufficiently resistant to hold a man with a barrow load. This work, as may be imagined, is dangerous to health. In Germany certain factories have attempted, with more or less success, to remove these mud deposits mechanically, and of late years certain spiral lifting devices have given very satisfactory results. The mud is raised and emptied into cars or carts that are constructed with a view to their economical transportation. It is important not to lose sight of the fact that these deposits, consisting of fine particles of earth combined with organic matter, are in reality a valuable fertilizer and when used for agricultural purposes have given satisfactory results. It would be interesting to know the value of the theory that these deposits when used upon soil to be subsequently cultivated in beets become an ultimate centre for nematode infection. If the decanted water is to be run into the river such deposits should be still further epurated, and this subject will be thoroughly discussed in a subsequent chapter.

**Beet-brushing.**—In the beet-sugar factories of Continental Europe the beets are generally taxed according to their weight, and therefore every effort is made to remove not only the water adhering to the surface, but also the dirt, etc., and to this end brushing devices have been used. There are many types of these machines that claim to remove 2 to 3 per cent of impurities still adhering to the roots; if only 0.17 per cent were eliminated the apparatus would soon pay for itself. There is a certain difficulty in keeping brushes clean, and if left unclean a partial fermenta-

tion follows. The brushes are of whalebone, chemically prepared, being dipped in ferric tannate.

An effective brusher and carrier of the DENIS-LEFEVRE * type (Fig. 44) are used in the United States, and give satisfaction. The apparatus has a slight slant to facilitate its working, and consists of a series of parallel cylindrical brushes rotating in the same direction. The main body of the brushes is of wood with iron axis, at each end of which are suitable movable bearings. The brushes proper are of whalebone, and the whole arrangement is placed between strong iron frames. At one end of the axis of each brush

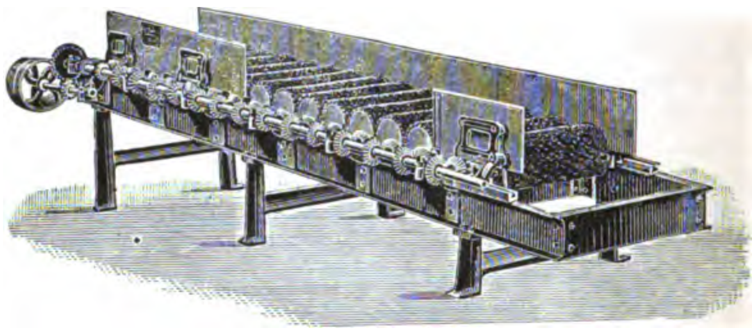


FIG. 44.—DENIS-LEFEVRE Brusher and Carrier.

is a small conical cog wheel, which gears into the pinion of a lateral axis, upon which the entire movement of the apparatus depends. Beets upon leaving the washer are distributed upon the upper end of the first brush and are turned and rubbed by each brush of the series, being constantly carried forward, while adhering small stones, earth, etc., fall below. Beets that are rotten never reach the end of the carrier. The brushes undergo a certain wear and must be renewed after two campaigns. As the brushes become worn they may be brought closer together, a special arrangement of bronze bearings permitting the change in position. The apparatus under consideration is large enough for a 150- to 200-ton factory, and as its working is very simple and requires but little power no special arrangement is needed for its installation.

These brushes need care and should be kept clean by repeated water-spraying, under no circumstances using hot water for this purpose, as it would soon act upon the glue of the brushes. They

* S. B., Jan. 1892.

should be carefully watched, as a stone will ruin them and fatty clays clog open spaces.

Numerous suggestions have been made for getting rid of the water adhering to the whalebones, among which may be mentioned a sort of regulating device placed beneath the brushes. The bones are first twisted and then allowed to spring. The brushes of these machines vary in width from 0.5 to 1.25 meters, representing an enormous difference in their daily working capacities, and revolve at velocities that vary from 40 to 50 revolutions per minute. Calculations show that a beet, from the time it runs on these brushes until it leaves, makes from 1000 to 1200 revolutions upon itself. The saving in the weight of beets that would have been taxed in accordance with some of the European fiscal laws is frequently $2000 during a single campaign; and furthermore, the weight of the beets being lessened the cost for their manipulation in the factory means a saving of at least $1000 for a plant of average capacity.

**Shaking carriers** in most cases are simply troughs with perforated bottoms (*A*, Fig. 45), the holes of which are elongated in shape,

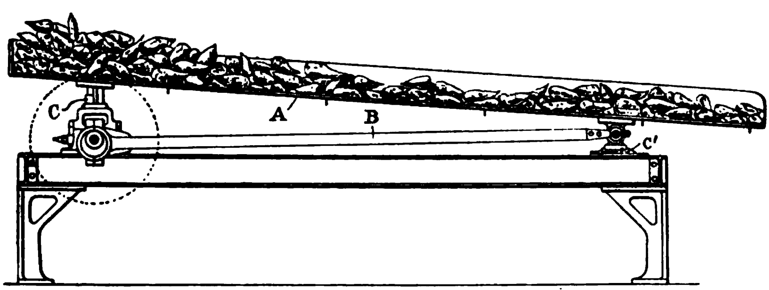



Fig. 45.—Shaking Carriers.

the larger dimension being in the direction of the motion of the root. These shakers rest upon supports *C′*, to which is given the alternating motion through the arm *B*. There are about 80 to 100 motions per minute. The most satisfactory machines are placed in a slanting position, under which circumstances the beets slide without any difficulty towards the lifting device. Experience shows that there are numerous advantages in making these shakers very wide, the object being to distribute the roots over a considerable surface, so that the man in charge may recognize at a glance a stone or a rotten beet and remove it from the lot. Under all circumstances every precaution should be taken to keep the perfora-

tion of the bottom of the appliance free from all possible clogging, and with frozen beets this offers, for some reason, an exceptional difficulty.

**A beet-lifting** combination at the extreme end of the shaker is a necessity, owing to the fact that the slicer is always placed in at an upper elevation. The bucket-lifting device can elevate beets 15 meters without difficulty. Some years since these lifts were placed in a slanting position, but the modern method demands that they shall be vertical. As a general thing these vertical bucket lifts have four wooden or iron supports, the buckets in most cases being of iron mounted on chains. Some experts claim that the double-chain arrangements are objectionable in that the wear and tear on them are not uniform, that is, that there are certain irregularities in their working. The buckets of this carrier pick up the beets either from a sheet- or cast-iron hopper, the latter being difficult to keep clean. The bottom of the hopper is rectangular in shape, almost exactly the same size as the chains and buckets, so that the broken particles of beets fall into the bucket and not to the bottom of the receiving receptacle. The arrangement prevents excessive accumulation of dirt, fermentation, etc. The space beneath should, however, be of considerable depth, and all deposits should be removed regularly twice a day, or every 12 hours. Another combination * that has given satisfaction consists in a sort of suspended bucket held in a position by counterpoise. This arrangement nearly permits one to touch the bottom limit of the bucket carrier without subjecting it to much wear. The chains used for these elevations offer nothing of special interest, except that they are made up of closed links to give them resistance in the work they are called upon to accomplish. They turn on two grooved pulleys, the motion being given by the one on top through suitable gearing, which has an up-and-down screw regulating device which gives the chains the necessary tension to effect the best results, a factor to be practically determined. If the tension is too loose it may slide on the pulley and even under the influence of an excessive load in the reverse direction to that intended. When this happens, there is necessarily some damage done to the carrying buckets. On the other hand, when the tension is excessive there is too much wear upon the chain, which experience shows is about 1 mm. on each side during a campaign. This means a considerable

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* B. Z., **22**, 773, 1898.

total lengthening and demands regulation, necessitating an entirely new chain after a period of years. These chains move at a velocity of 15 to 30 meters per minute. A ratchet movement with teeth of reasonable size, few in number, prevents the chain from falling

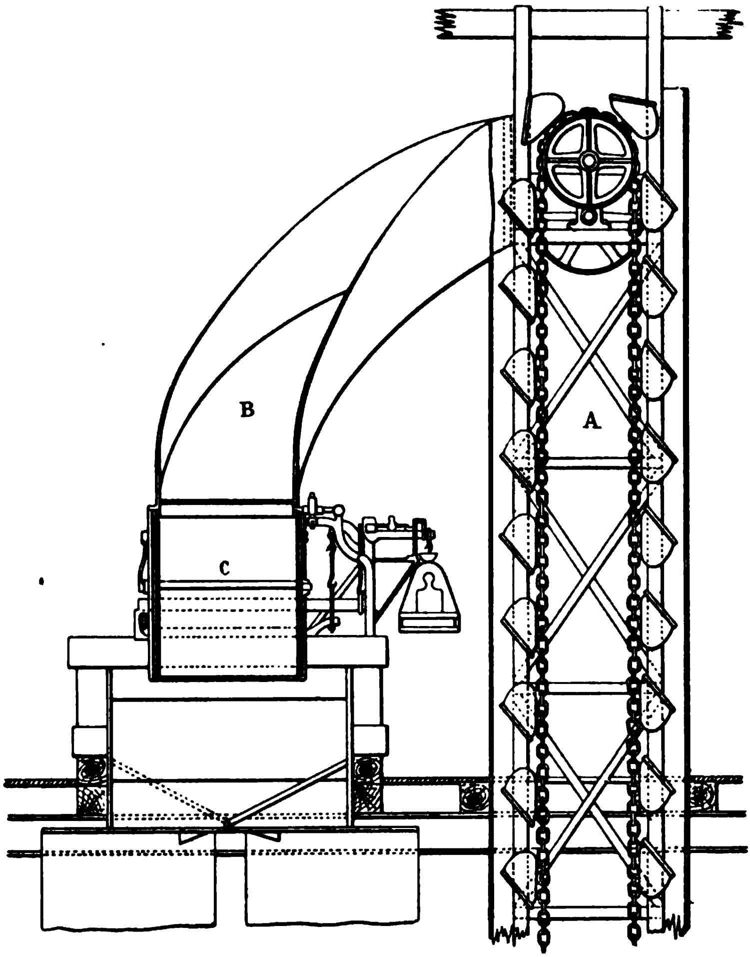


FIG. 46.—Beet Lift, Iron Buckets, and Chains.

backwards when the appliance is put out of gear. The buckets must be strong and well made, with their upper border bent outwards so that the water from the upper ones will not fall into those beneath. The bottom of the bucket is somewhat rounded. If the requisite precaution has not been taken to separate the water

from the beets it falls into the feeding hopper of the lift. The water must be allowed a free exit at the bottom into the canal, yet in spite of every care, a certain quantity always finds its way into the bucket and is carried with the beets and emptied into the beet slicer. The general arrangement of these beet elevators is shown in Fig. 46, *A* being the elevator support, chains, and buckets, and *B* a curved hopper guiding the beets to the slicer. It is so arranged that the filling is continued during the period of weighing, and when the weighing machine is emptied the contents of the hopper are about sufficient for the next weighing. In certain cases this work is automatically accomplished. In the best combination the bottom of the hopper is perforated so as to allow the beets to receive a final straining before being weighed, the water running into a pipe which communicates with the waste-water sluice.

## CHAPTER V.

### WEIGHING OF BEETS.

THE importance of weighing beets before slicing is not always appreciated in American beet-sugar factories. In Continental Europe, on the other hand, the practice is very general, and in most cases the manufacturer's tax is based upon it. The weighing of beets is desirable in order to control the quantity of roots delivered and their tare, and to determine the number of tons on hand as a guide to the manufacturer. Notwithstanding the precautions generally taken errors, frequently very important ones, occur, due to fraud or other causes. Hence a thorough organization must characterize the reception of the beets, so that if there is any irregularity it may be detected before it is too late. At all times one should know the exact number of tons of beets that are siloed and not yet sliced, even when outside roots are being simultaneously used with those on hand. The necessity for such precautionary measures is more essentially realized toward the end of the campaign, when measures must be taken to keep in the best conditions the roots that shall remain so that the slicing may be extended over the longest possible period.

In Germany some few factories have altogether abandoned the weighing after washing, and regard as accurate the showing of the reception scales when the roots are brought in by the farmers, of course making due allowance for the tare; or they may calculate the weight after the diffusion battery is full. Both of these methods are very faulty and should be abandoned, as when the weight of the beets being sliced at the factory is not accurately known the first essential for the control of the sugar-manufacturing process is absent; neither is it sufficient for the control of the manufacturing process to ascertain how much sugar remains in the after product.

There are too many chances of error and fraud for entire reliance to be placed upon this method.

The system of scales generally used for accurately weighing the roots before they enter the slicer has a hopper to receive the beets delivered and the loading continues until the equilibrium is established, when the communication between the distributor and the hopper is at once closed. If there are a few beets in excess these are removed and placed in a basket, or some may be added to the hopper if the exact weight is not obtained. By older modes the man doing the weighing would keep the record on a blackboard or by other means, but this was not very reliable, as few scales can be considered absolutely accurate. One cannot do better than to depend upon automatic scales, some of these combinations working with considerable accuracy, although this is not true of all. As soon as the normal weight is exceeded, the scales, through a special combination of levers, close all communication with the hopper, and the fact that a few beets must be added or taken away shows that reliance must be placed in the weigher. A device has of recent years been adopted by means of which the hopper full of beets cannot be emptied until the weight is absolutely correct. The automatic scales generally used in Germany are known as the CHRONOS. When the desired weight is obtained this scale closes the distributing trap, and any excess of weight is automatically registered by a lever with counterweights, while the normal weight is recorded on the principal register. When the hopper automatically empties the beets into the slicer, returns to its original position and opens the distributing register, it is no longer necessary to have some one in charge, but a man must always be on hand to follow the beets from the lifting buckets to the hopper distributor.

The working efficiency of the slicer and the beet lifts is not necessarily always the same, and the lifts must sometimes be stopped, as for example in cases where the distributors, hopper, scales and slicers are all full. If the hopper is overfull some one still is needed to throw out of gear the cog wheels commanding the motion of the lift, otherwise there would be certain danger of an accident. This stoppage must not be effected too soon nor too frequently, as the action of the washer and the hydraulic distributing device would necessarily be very much deranged; for once the signal has been given the machinery must be stopped all along the line. After each interval of this kind several minutes must necessarily elapse before the beets again circulate with the

desired regularity. During this period the slicer is soon empty and poor cossettes are the natural results. There are generally two slicers in communication, each with automatic scales, and these are alternately filled by simply oscillating a slanting trap distributor that communicates with each in turn as the occasion demands a change.

# PART II.

## *EXTRACTION.*

## CHAPTER I.

### BEET SLICERS.

For the purpose of extracting sugar, beets are sliced into long strips, which offer, when brought in contact with water, a considerable area for absorption. These slices, or cossettes, should have a long, smooth surface presenting a uniform section throughout their length and should not be mixed with bits of beets of no definite shape. To obtain these requisites a special apparatus, known as a beet slicer, is used which consists generally of a horizontal disk with a rotary motion. Another type, based upon centrifugal force, has not met with general favor. Most of the slicers now used differ only in the size of the disk and the arrangement of the cutting blades.

**The type** generally preferred consists of a cylinder at the bottom of which is a circular horizontal disk with blade attachments. The hopper which feeds the disk with beets has not always been cylindrical. In the old types of beet slicers only one-half of the revolving disk was brought in contact with the beets, while the other half was free and bore the conical gearing attachments, which gave the requisite motion and permitted a rapid change of blades without unmounting the feeding hopper. In the more modern apparatus effort is made to give the greatest possible cutting surface to the revolving disk, the motion being transmitted from above. Other modifications have made it possible to receive the beets upon the entire disk, allowing spacing for the blade attachments.

**The cylinder** forming the hopper should be so arranged that

the space over the disk with its knives may be covered with beets, which will slide toward the bottom. Its lower portion consists of two concentric sleeves which are continuous, with the exception of suitable openings for the introduction of the blades and their holders. The width of the annular space near the disk is a fraction greater than the length of the frames with their knives. It is not desirable to give any arrangement to the sleeves by which the hopper thereby formed may be raised; it is better to have a sort of hood. The exterior portion forming the hopper, however, is 1.5 to 2 meters high, and the beets fall without much friction as the work of the disk and its knives progresses, falling more and more rapidly as the velocity of the apparatus and the number of the slicing blades increase, that is, as the capacity of the apparatus becomes greater. In the interior of the cylinder the sleeve and the hood should have no projecting parts, such as rivets, bolts, etc.

To prevent the beets from being suspended and forming an arch one against the other the lower part of the hopper is made wider than the top. With the same idea in view, projecting arms are frequently placed on the hood or dome covering the top of the axis and its gearing and made to revolve in the opposite direction to that of the disk and knives. When these arms are 300 mm. above the knives they have little or no influence upon the beets being sliced, but the roots cannot remain suspended in the cylinder. This arrangement is of exceptional value when handling frozen beets. It is interesting to note that the height of the feeding cylinder above the disk varies very much in different countries, but experience shows that it is not desirable to have it less than 1.5 meters. The Austrian beet slicers frequently have feeding cylinders over 2 meters high, thus forming a column of beets of sufficient pressure to keep the roots well in contact with the knives; furthermore, their weight prevents any suspension of the roots in the hopper, as previously mentioned. It is evident that when the height of beets above the knives is not sufficient to produce the desired pressure the roots are simply carried forward with the disk, the knives giving only a few very poor cossettes. It is desirable in the vertical cylinder to have several openings closed with vertical bars which permit one to see exactly in what manner the roots are being distributed during their downward movement.

**The circular disk** bearing the knives is wedged upon a vertical axis on the surface of which are numerous regular openings to admit

the blades and their holders. In most German beet-sugar factories the diameter of the horizontal disk is from 1200 to 1500 mm., while in some other countries, Austria for example, it is 2500 mm. The velocity of the smaller machines reaches 100 to 150 revolutions per minute, while for the larger slicers 50 revolutions are sufficient. The fact is that the actual velocity on the outer periphery of the disks in the two cases is very nearly the same, being somewhat less for the larger disks. It is generally admitted that the large disks revolving slowly give better and more regular cossettes than do the smaller rapidly moving machines; but as the quality of the cossettes involves numerous considerations, it frequently happens that in the long run the smaller machines give the better results.

Owing to the limited number of revolutions made by the Austrian slicers, their efficiency as regards working capacity is not as great as one might suppose when the number of cutting blades is taken into consideration. In all well-organized beet-sugar factories there are two beet slicers, the one working while the other is being made ready, which operation consists in renewing and adjusting the knives. This arrangement permits one to give the care to the work that it demands, and in the end means a saving of money. Too little importance appears to be given to this detail, and a single slicer is frequently kept running almost night and day, stopping only when it becomes necessary to change the knives. The large disks demand much more time for a change of blades and for removing stones, etc., that have fallen into the knives than do the smaller apparatus, and there arise many arguments for and against the various types of slicers used.

The slicing efficiency of these appliances depends as much upon the number of cutting blades as upon the velocity of the revolving disk. The number of frames and blades attached to the disk of a slicer varies widely. Aside from the fact that there are more frames for holding the knives on a large disk than in the smaller apparatus, even on disks of a given dimension the number of knives is extremely variable, depending upon their shape. Allowance should also be made for the difference in spacing between the blades, these spaces being of greater or less length and width.

**The number of openings** for frames in a disk of a given diameter is necessarily limited, otherwise the spacing left would not be sufficiently strong to resist the strain to which they are submitted. In order to overcome the danger of rupturing disks which contain an exceptional number of blades and frames, Hillebrand joins the

outer periphery of the disk with the centre by suitable oblique ribs (Figs. 47 and 48). These form part of the iron casting of the disk and are placed underneath, resulting in a strong, resisting surface notwithstanding the fact that the frames and blades on the surface almost touch. The iron ribs in no way obstruct the escape of the cossettes. By this arrangement the same work may be accomplished as with any other slicer, but at a considerably reduced velocity. It must be noted, however, that though the efficiency of such a machine is very much greater than has hitherto been

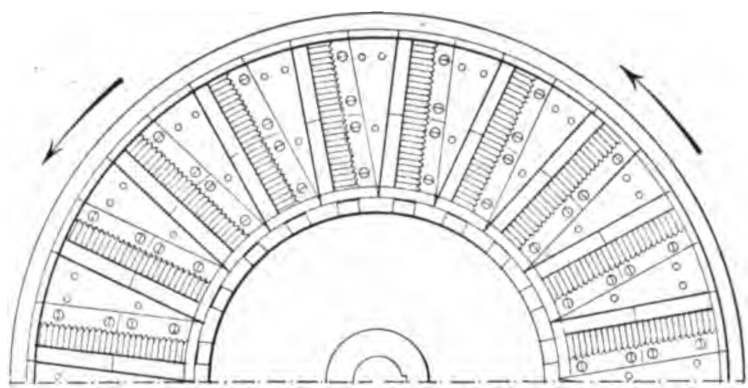

FIG. 47.—Top View of Half of a Circular Disk, with Frames and Knives.

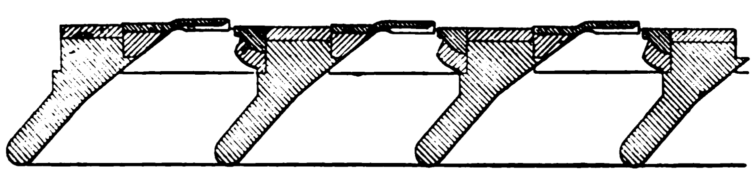

FIG. 48.—Section of the HILLEBRAND Disk, showing Strengthening Ribs.

attained, more power is needed for its operation. Furthermore, the arrangement is not as satisfactory as is generally supposed, for when the blade removes a slice, or cossette, a certain interval of time must elapse before the root can fall to the level of the portion removed, otherwise the beet slice would not have the requisite thickness and in some cases would be reduced to a pap. This unsatisfactory condition would necessarily exist at those points of the HILLEBRAND disk where the frames of the blades are too close together, if the velocity of the disk is not considerably lessened. Hence the looked-for results are not realized.

KARLIK * declares that knives on a disk of 2.5 meters diameter turning on the outer circumference at a velocity of 5 meters per second should have a spacing of not less than 50 cm. in order to give satisfactory cossettes. Evidently such spacing is not practicable except with the enormous Austrian beet slicers, and, furthermore, the slicing capacity of the apparatus is considerably lessened under these conditions. The advantage of a moderately slow revolving disk is not fully demonstrated, but there can be no doubt that when the knives are not called upon to do their work too rapidly the danger of breaking the cossettes after they leave the blades is considerably lessened, while on the other hand the greater the velocity of the slicer the shorter will be the interval of time given the cossette to change the direction it has received, and the result will be one long-continued fibre which is one of the essentials for its subsequent successful manipulation. In order to attain this end numerous experiments have been made, but whatever be the mode adopted the first important requirement is that the disk be absolutely perpendicular to the vertical axis to which it is wedged, otherwise the roots coming in contact with the slicing blades would simply jump up and down and be very irregularly cut. In order to make the 90° angle a mathematical certainty it has been proposed that the disk be planed down to the desired horizontal after it is fixed in position.

**Inclined disks.**—To overcome the centrifugal action of the disk during its revolution, which always tends to throw the roots being sliced towards the outer periphery, PAULICK proposed to give the frames and blades a certain slant. The general arrangement is shown in Figs. 49 and 50. *A* and *D* are the knife holders with blades in the disk *E*. The transverse section shows how the disk *E* is wedged on the vertical axis *h*, and also the position of knives. This idea, with some variation, is applied to most beet slicers, but it remains to be demonstrated within what limit it accomplishes the object in view.

**Notched disks.**—The slicing blades, as will be presently explained, have a jagged upper surface, while the disk is generally flat. It has been suggested that the notches of the blades find duplicates in the disks, so that the beets after leaving the knives will continue in the same position in which they were during the slicing. In the PUTSCH † slicer there are concentric notches on

* B. Z., **27**, 212, 1903. † N. Z., **11**, 197, 1883.

the surface of the disks in which slide the ribbed surface of the sliced beets. By this means the roots are supposed to be kept from dancing on the disk, and simply glide from one slicing blade to another. Unfortunately, however, the circles of the disks are concentric, while the portion of the circle which forms the back

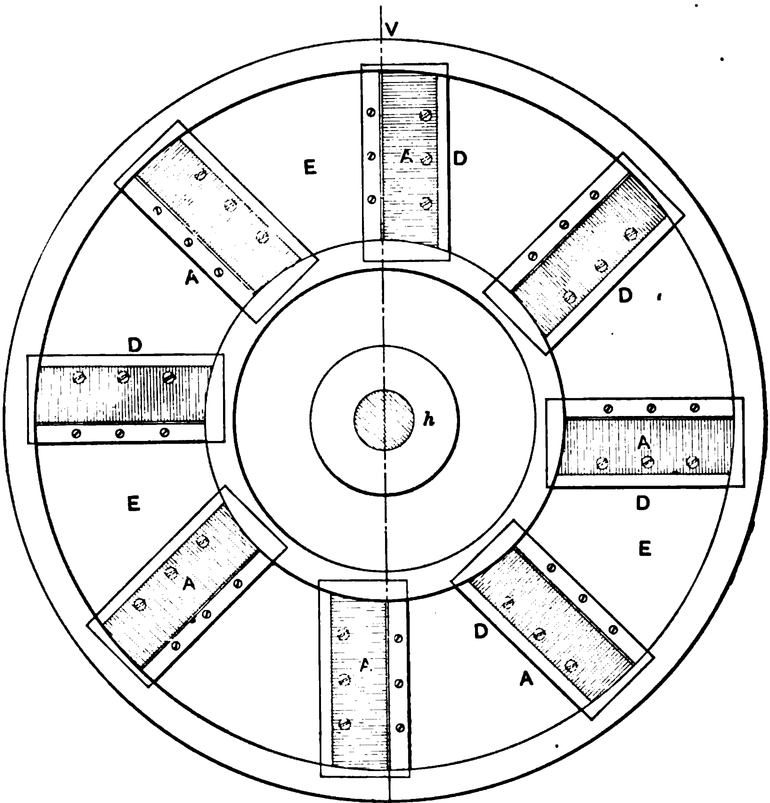


FIG. 49.—Plan of PAULICK, with Slanting Blades and Holders.

edge of the knives has the same radius, and such being the case there is no absolute connection between the two. It is, therefore, doubtful whether the notches accomplish their intended purpose, for do what one may no appliance has ever satisfactorily prevented the beets from dancing on the disk's surface. No knives have ever been made whose back edges have concentric circles corresponding to those of the disk of the slicer. Another disadvantage of the notched disks is that they require the use of

a special type of slicing knives, as with other knives the grooves would no longer correspond. This does not permit a change in the shape of the blades to meet the requirements of beets of special qualities, a contingency frequently to be met.

**The frame openings in the disks** should have the same shape and size as the blade holders. In the earlier types of beet slicers the axis of these openings was in the direction of the radius of the disk, and thereby the position of the beets was changed as soon as the cutting commenced. In most modern slicers the cutting edge of the blades is in a direction diverging towards the disk's centre, and the knives by this arrangement cut the beet in a perpendicular direction. The arrangement is more clearly shown in the plan of the Paulick slicer (Fig. 49). The openings in the disks should be mathematically concentric, otherwise there would be no possibility of a continuous cutting action of the blades. The objectionable results that would follow are shown and discussed under another caption. A millimeter variation in distance from the centre would be sufficient to influence the regularity of the cossettes in a most important degree. In order to hold the beets in position during the cutting, *counter blades* are used, which are fixed a few millimeters above the highest portion of the knives. For small beet slicers one of these counter blades is sufficient.

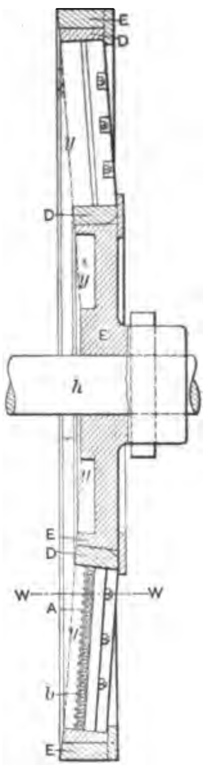

Fig. 50.—Transverse Section of Disk.

**Beet-arrestors.**—In order to prevent the beets from being carried forward by the rotary motion of the disk vertical plates are arranged which are intended to stop and retain the roots. Their height is very variable, but experience seems to show that it need not exceed 20 mm. When these plates are exceptionally high the beets tend to cling together and form an arch under which the blades of the disk do not work; on the other hand, the nearer they are to the revolving disk, the better will they be able to retain the smallest particle of beet in position. To have them too near the cutting blades, however, presents certain objectionable features;

for example, if small stones should be present they would be forced against the knives and destroy their cutting edge. The spacing may be regulated to suit the emergency by an adjustable rod placed at the lower edge of the disk. If observation shows that stones are being constantly brought into the slicer with the beets, then the height of the arrestor should be about 5 to 10 mm. above the disk.

It is also proposed to give to these plates a slanting position so that the acute angle thus formed will carry the beets around with the disk and keep them well in position during the slicing. The sheet-iron arrestor of the PUTSCH * combination moves upon an axis and holds the beets in position against the disk by a counterpoise. Suitable slits are made along its surface through which small stones may escape whenever there is exceptional resistance. The advantage of these openings is that the arrestor does not in most cases change its position when coming in contact with an obstruction, if not too large, as is the case with other arrestors which have no slits. Furthermore, the tip ends of the roots that are being sliced frequently pass through and hold the beet in position, which permits the knife to give an exceptionally long cossette.

The PUTSCH † device for bringing the beets in contact with the slicing blades consists of a wheel placed over the disk with frames holding the blades. The direction of the axis of this wheel is that of the radius of the disk. Fig. 51 explains itself;

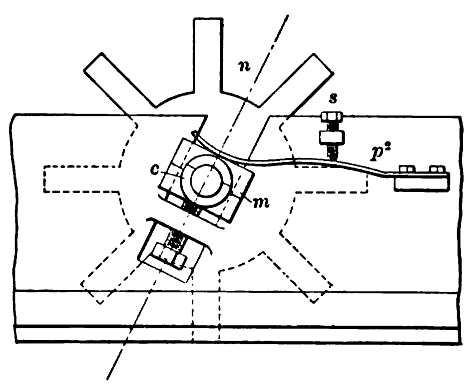


FIG. 51.—PUTSCH Beet Holder.

the axis $c$ slides up and down the guides $m$; it is held in position by a small spring $p_2$, which is regulated by the screw $s$.

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* D. Z. I., 25, 1540, 1900. † Z., 48, 936 and 939, 1898.

If a stone comes in contact with the device in question it simply slides along *m*. Another very simple device for bringing the beets in contact with the slicing blades, resulting in very long and regular cossettes, is shown in Fig. 52. Several wheels with strong iron hubs are placed on the same axis; they each have projecting wooden arms and turn independently of each other. When the plate with the knives revolves, the roots are carried forward with a rotary motion and meet the projecting arms, which offer just enough resistance for the beets to be held during the small interval of slicing. When the next knife presents itself

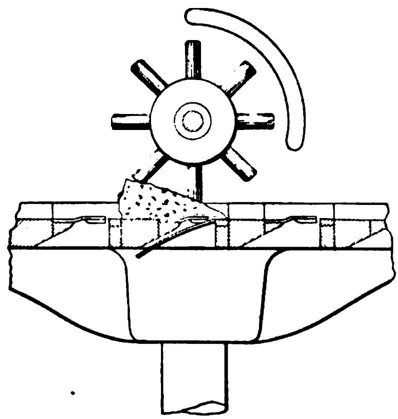

FIG. 52.—Beet-slicing Regulator.

the beet-slicing regulator has made a slight movement forward in the opposite direction, still holding the root in position. These movements continue until the work is completed. The beet slicer to which the arrangement was attached was 1.28 meters in diameter, had twelve knives and revolved at a velocity of 100 revolutions per minute, slicing 600 tons of beets per diem.

**Removal of foreign substances.**—In order to remove all foreign substances, such as stones, leaves, etc., which are introduced with the roots during the operation of cutting and collect in the slicer, openings with suitable doors are placed at some spot in the hopper near the counter blades, and just below numerous steel rods fixed in a series of small holes. When the characteristic dull noise of two hard substances coming together is heard, indicating that the cutting blades are attempting unusual work, the machine should be immediately stopped, otherwise there would evidently be danger of a breakage of the blade frames, etc., and

the longer this condition is allowed to continue the greater will be the damage done. The removal of these hard particles is accomplished through the openings in front of the counter blades which were mentioned above. These act also as collectors of foreign substances. The obstructions are found underneath the beets, which are kept from falling by the rods of iron or steel. When the roots are thus suspended a certain number always remains to be sliced, which, as they are not pressed against the slicing blades, are tossed about and result in cossettes of very poor quality. Some authorities point out that to suspend the beets only over the arrestor has the advantage of rapidity and gives finally more satisfactory results. If the foreign bodies are not to be found at the arrestor it is advisable to remove a frame with its blades from the disk and revolve the slicer in the opposite direction, when all the obstructions will be thrown out through the opening.

**Stone separators.**—Some twenty years ago it was proposed to place on the disk two frames without knives, the openings being such as to allow the stones but not the beets to pass through.* Another arrangement of more recent construction is worthy of attention.

Messrs. Dubois and Poulain, by a specially constructed plate placed beneath the slicing blades, have overcome in a large measure the difficulty caused by sand, gravel, etc. The arrangement is shown in Figs. 53 and 54, and needs very little description. It consists of movable hollow bars, *TT'*, through which pass smaller bars of shorter diameter having consequently a free rotation upon themselves and offering very little resistance. They are held in position by the steel frame *ab*, *c'* is the disk of the slicer. Another combination consists in having in the disk *c'* a series of conical holes through which the gravel, etc., can fall. This stone and gravel separator can be placed on any beet slicer.

The Maguin stone remover (Fig. 55) has also many interesting characteristics. It consists of a hollow chamber *E*, placed in the direction of one of the disk's radii, a few millimeters from the surface of the disk *A*. The spacing may be modified to meet the requirements of each special case, thus acting at the same time as a beet arrestor. The stone enters the interior of the device where it is held in position by the clogging of broken bits of beets and cossettes that collect after a few revolutions of the slicer, and a

* S. I., **20**, 621, 1882.

small hole in the feeding hopper or cylinder permits the removal of the obstructions from *E*.

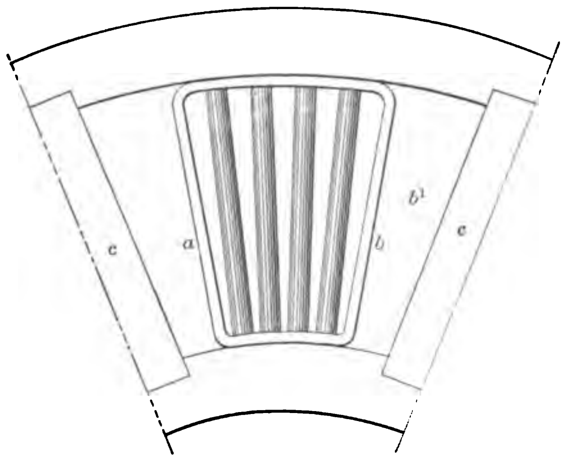


FIG. 53.—Plan of DUBOIS and POULAIN'S Beet Slicer Stone Separator.

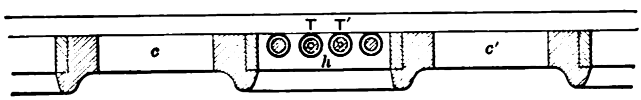


FIG. 54.—Section of Disk with Bars.

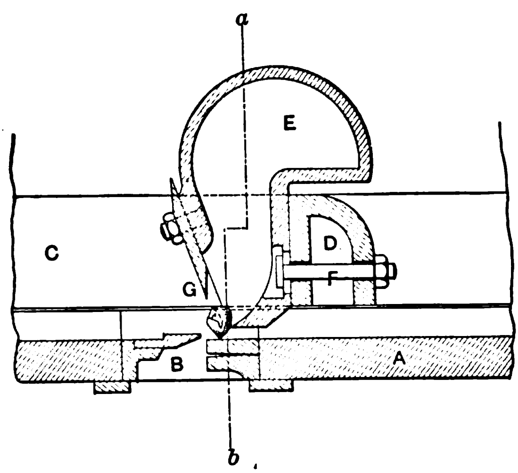


FIG. 55.—MAGUIN Stone Remover.

**Clogging.**—Do what one may, there is always a certain amount of dirt, straw, etc., which, while not actually breaking the edge

of the knives, considerably diminishes the efficiency of the machine by clogging and stoppage. Sometimes, because of exceptional changes of temperature the beets undergo a second growth, or when by atavism they may have become annuals, the beets are fibrous, and these fibres will clog the blades and may be removed by the use of a brush *S* (Fig. 56), which revolves with considerable velocity in the same direction as the disk *R* with its blades attached. The apparatus accomplishes its work most satisfactorily.

**The transmission of motion** to beet slicers may be accomplished in several ways. Conical cog-gearing combined with suitable

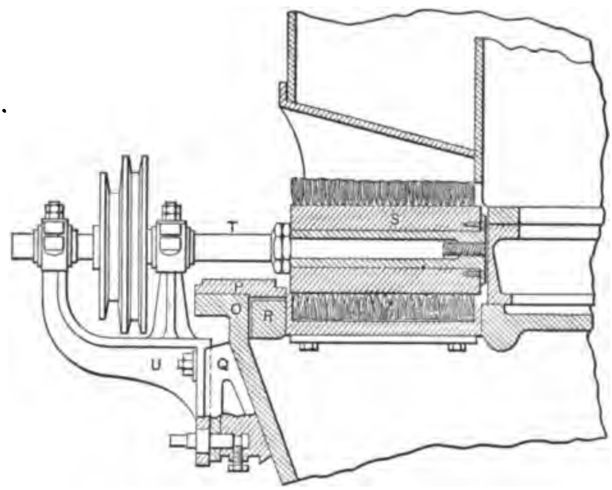


FIG. 56.—MAGUIN Blade Brusher.

pulleys and belting and the now obsolete mode of gearing placed over the slicer meant considerable loss in efficiency, and the action of the feeding hopper consequently was interrupted. In most of the modern combinations the conical gearing is placed under the revolving disk, of which the German type shown in Fig. 57 is an example in point. The axis of this machine is supported by pivot and socket, but it is doubtful whether this mode is as desirable as a combination ball and friction plate. The lubrication of the upper portion of the axis is accomplished by a very simple device shown in the drawing. The cossettes as they are produced fall into a bottom section and are forced to pass out through a side distributing hopper. When beet slices are intended to feed circular diffusion batteries the feeding hopper must circulate and

the mode of transmission, as shown in the last mentioned slicer, would not be possible. The motion in the most improved CAIL combination is given from above the beet distributing cylinder, which arrangement permits one to watch closely all the moving

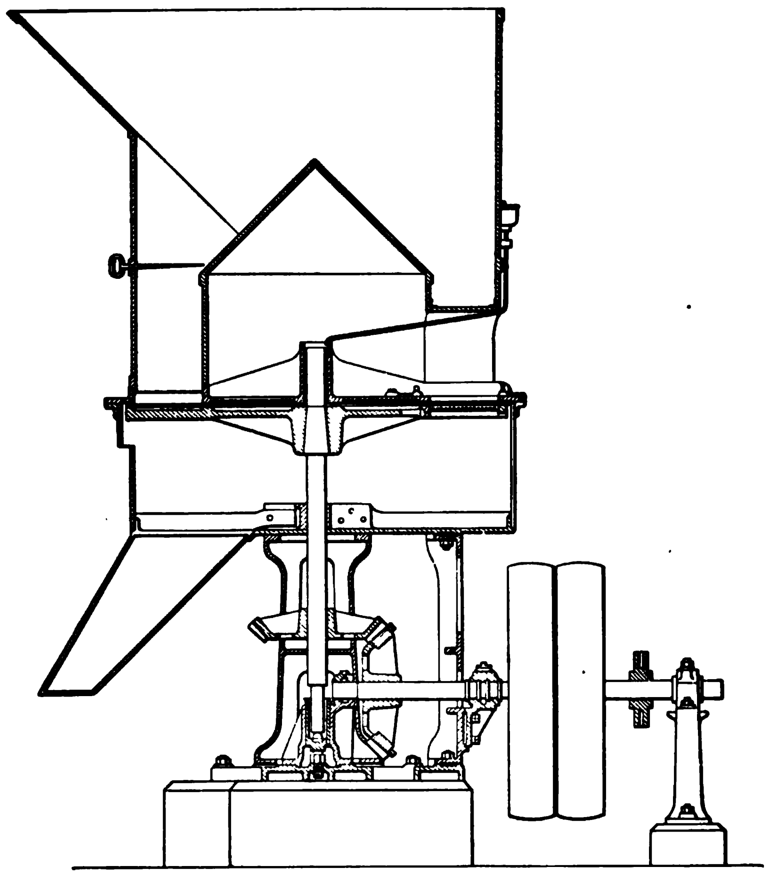

FIG. 57.—German Beet Slicer.

parts of the gearing. The beet slicer should be entirely covered so that particles of dirt, etc., that are brought up by the beet elevator will not be emptied into the gearing. The FIVES LILLE beet slicer also receives its motion from the top, the gearing being entirely covered by a cylindro-conical hood, occupying the centre of the feeding hopper. Very much the same arrangement is adopted in the MAGUIN slicer shown in Fig. 59. One of the conical

gearings with wooden teeth should have an extra wheel in reserve in case of accident. The trolley upon which the distributing cossette hopper revolves on a suitable ledge is clearly shown in the drawing. The cossettes after leaving the knives first fall into a truncated cone placed beneath and then into the distributor which conveys them to the diffusors.

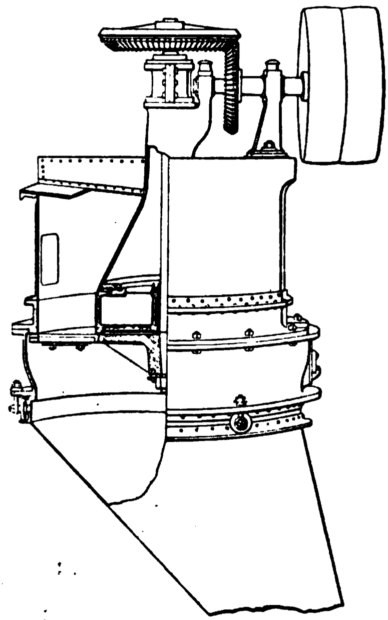

FIG. 58.—French Beet Slicer (CAIL).

**Direct transmission.**—Certain types of appliances have their own motor and electrical attachments, and having the advantage of complete control of the velocity of the disk they are equal to any emergency. While such combinations are certainly advantageous their cost will necessarily prevent their general introduction. Among the interesting types of slicers with direct transmission may be mentioned the BREITFELD and DANEK apparatus, in which two steam cylinders are used, as shown in Fig. 60. By suitable combinations the slicer may be placed in and out of gear. As fast as the cossettes are produced they are projected into a lateral distibuting hopper by means of a horizontal revolving disk which receives its motion through belting connecting with the main axis whose velocity is less than that of the disk. Whatever be the construction of the slicer when the blades are to be renewed the circular disk holding the frames with the knives must be turned by hand until in the desired position. As considerable effort is necessary to force the disk to revolve, it is desirable to have some suitable attachment or combination to facilitate the operation, and there are many devices with this object in view.

**Distributing cossette hopper.**—Several distributing cossette hoppers have been shown in the machines illustrated in the foregoing pages. It frequently happens that at certain periods there is no diffusor ready to receive the sliced beets, yet the slicer cannot

be instantly stopped. The importance of having a cossette distributor of reasonable capacity is thus seen, as it allows the beet cutting to continue in case of a momentary irregularity in the battery's working.

**Other combinations for beet slicers.**—Since the first attempt at beet-sugar making continual efforts have been made to construct

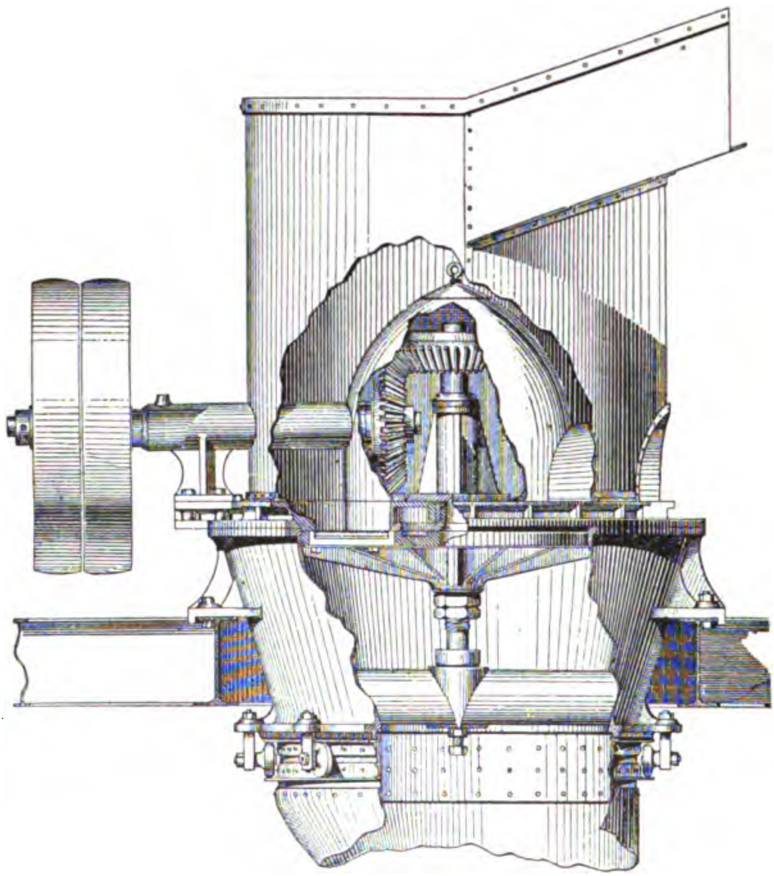

FIG. 59.—French Beet Slicer (MAGUIN).

beet slicers upon more rational principles than are illustrated in existing machines. The slicing efficiency of the blades attached to the revolving disk is most varied and depends upon where they attack the beet, the action near the centre differing from that at the extreme outer periphery, with a difference in velocity in the two cases, and for this reason efforts have been made to give the

blades a straight motion rather than a circular one. NIKISCH proposed that there be used a sort of beet plane consisting of a rectangular disk with knives having an alternating motion backward and forward, the slicing being accomplished on both movements. STENTZEL * and REBOUX † built a machine of this kind, but it was never generally introduced into the factories. Another arrangement on the same lines consisted of an EWART ‡ chain holding a series of frames with their slicing knives. These passed over two drums

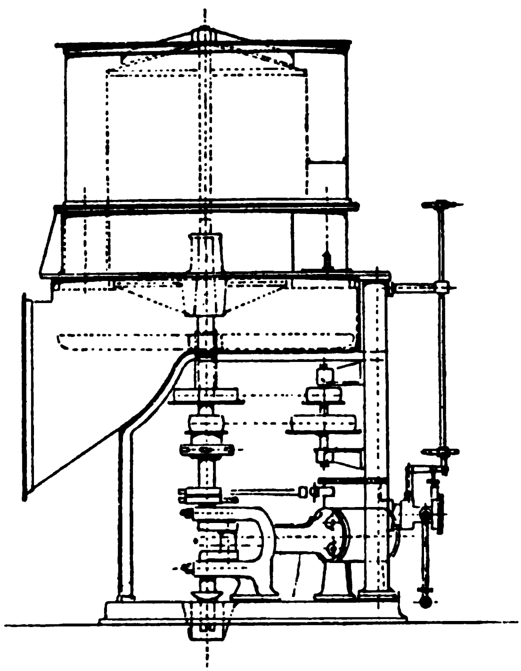

FIG. 60.—Austrian Beet Slicer, Direct Action.

which raised the knives against the bottom of a hopper filled with beets. The main objection to all such combinations is their limited efficiency, and centrifugal slicers were and have remained a far more rational device, avoiding the objectionable features of horizontal slicing. Efforts were made to place the knives and holders upon the generatrix of a drum. The first idea of placing the knives upon the periphery was suggested by NIKISCH § and the plan assumed a practical shape under the guidance of RASSMUS ‖ (Fig. 61). The

* N. Z., **10**, 153, 1883. † La. S. B., **12**, 345, 1884. ‡ N. Z., **12**, 85, 1884.
§ B. Z., **6**, 170, 1882. ‖ N. Z., **10**, 219, 1883.

beets fall into the interior, *c*, of a revolving cylinder placed in an outer casing, *b*, of the same shape; it holds a series of blades, *i*,

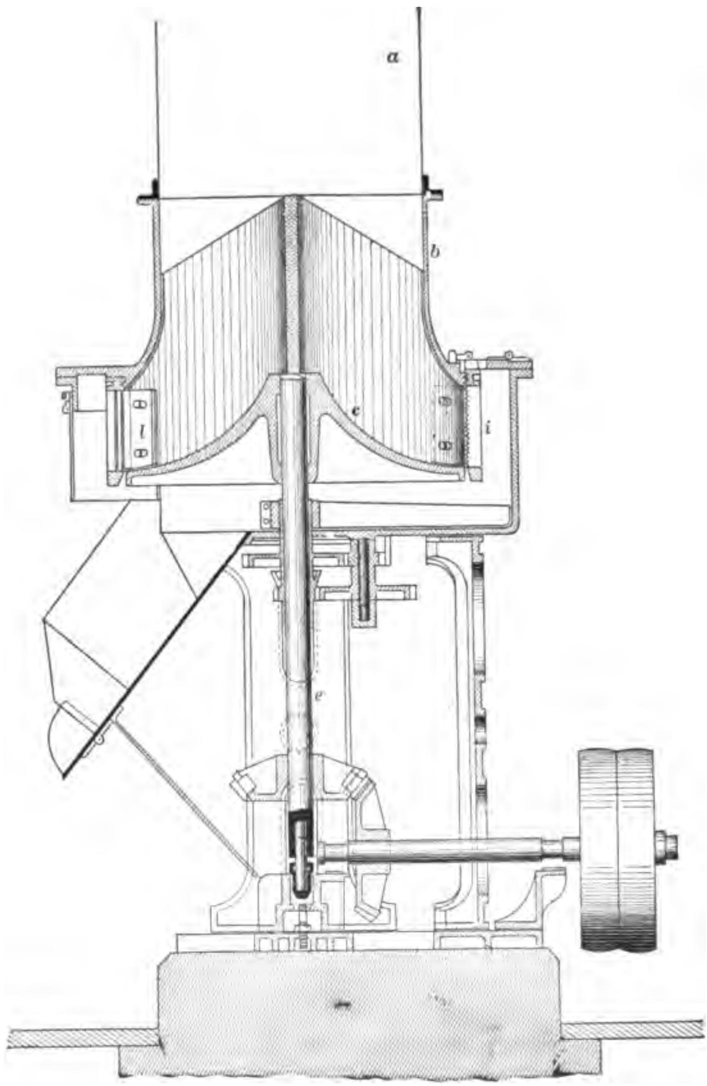


FIG. 61.—RASSMUS Beet Slicer.

and their frames, and the movement is given by bottom conical gearing. The beets are thrown against the knives and the cossettes fall into the compartment below and are forced into the

lateral slanting hopper by the rotation of a horizontal scraper receiving its motion through a suitable gearing connected with the vertical shaft *e*. While this apparatus held its own for a long period of years it has now become obsolete.

In Germany LITZKENDORF * has constructed a slicer of very original shape. It consists of a cylindrical drum, turning in the interior of a calender mounted by a truncated cone which is used as a hopper for beets. The blades are attached to the drum in the direction of its generatrix, and the resulting beet slices fall in its centre. Special divisions are placed in the hopper to keep the beets in position during cutting. As the beets do not press directly upon the slicing knives the harm done by stones and other impurities is very much less than in most of the methods of slicing. Each of the divisions of the hopper correspond to a special compartment or box of the truncated hopper, in which stones and impurities are separately collected. To change the knives it is necessary to withdraw the drum holding the blades, but this may be instantly replaced by another drum prepared in advance with knives all carefully sharpened.

One of the most unique beet slicers, and in many respects the most practical of any that has come to the writer's notice, (Fig. 62), has slicing knives that are all parallel to one another and close together. They travel at exactly the same velocity and the beet is held in position during its slicing. The drum has a cutting diameter of 1.20 meter and is 33 cm. wide; it works on a horizontal axis and has eight blade holders on its exterior. Each holder contains six parallel knives, in series of two, which may be instantly regulated. The eight holders consequently represent twenty-four ordinary knife holders and in reality contain 48 blades 165 mm. in length in 24 parallel rows of two blades each. The beet as soon as it enters the machine, is carried forward by the revolving motion of the drum towards a section that becomes smaller and smaller, a specially shaped cast-iron nose offering resistance. As the beet is carried parallel to the knives, which are very close together, strips of great regularity are obtained. At the other end of the nose obstructor is an opening into which fall small stones, etc., which have done little or no harm to the slicing blades. This receptacle may be emptied as often as the occasion demands.

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* Z., 50, 97, 1900.

The knives may be removed with the same ease as in any ordinary beet slicer. As the MAGUIN slicer has a considerable number of blades and may be made to revolve at a great velocity, its working capacity per diem is very much greater than that of other slicers hitherto constructed. At 60 revolutions per minute it can slice 20 tons of beets per hour, and the saving in power is said to be about 50 per cent as compared with most other slicers.

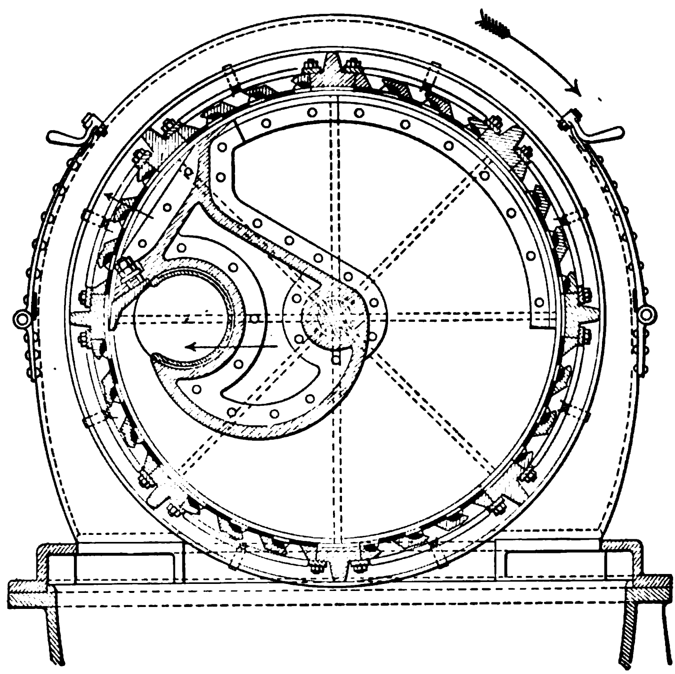

FIG. 62.—MAGUIN Fixed-blade Slicer.

In the majority of beet-sugar factories where these slicers have been introduced two are used, and whether they work together or separately they have an independent motion. They are generally placed on a floor beneath the weighing apparatus from which the beets fall into a double-branch distributing hopper. When both slicers are working, this double arrangement allows 400 tons of beets to be sliced in twenty-four hours. In some factories only one is kept working, so that, if for any reason repairs have to be made there need be no general stoppage. The inventor says the following advantages may be claimed:

The possible maximum of regular slices being obtained, the circulation in the diffusion battery is better than it is with most beet slicers, which do not give perfectly regular cossettes. Under these circumstances the sugar in the slices is exhausted under very favorable conditions which means an increase in the working capacity of the battery. The yield of these slicers is large with comparatively low speed. The space occupied by the two slicers is not much greater than that needed for one of the old types. The stoppages necessary to keep the blades in good condition are reduced to a minimum. It is claimed that fibrous beets, such as annuals, are easily sliced by providing the slicer with a knife-brusher. The use of special blades is no longer necessary. As all parts are standard in size they may be renewed at a moment's notice.

**Feeding and care of beet slicers.**—Beets are thrown directly into the slicers from the hopper that connects with the weighing apparatus, and if the arrangement of the building does not permit this the roots are carried to the slicers by means of an elevator. Evidently the first mentioned mode is the better and should be adopted as the contents of the feeding hopper can be better regulated, the beets being constantly in view of the person in charge of the automatic scale, while by the other arrangement they drop into an upper receptacle, the interior of which cannot be examined without considerable trouble.

Upon general principles beet slicers should be kept as full as possible, and it is for this reason that the control should be in charge of the weigher. When an elevator is used it may be desirable to have an electric device to throw both the elevator and the beet slicer in or out of gear simultaneously. In the VOLQUARTZ * electrical arrangement there are two slap valves on the sides of the beet slicers. The lateral pushing of the roots forms an electric contact. When they press upon the lower valve a contact is established that electrically puts the beet lift into gear, so that the hopper of the beet slicer becomes full, and when the beets push against the upper valve they cease to be emptied into the hopper. This arrangement is somewhat complicated, and a simpler device with the same object in view and working upon the same principle, consists in having an electric alarm bell, the man in charge of the lift acting according to the signal. This, however, means additional expense and the employment of another person.

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* Z., **49**, 407, 1899.

Beet slicers should be cleaned as frequently as possible, for there are always certain small corners, etc., where the broken cossettes can collect and rot and a thorough weekly washing is essential. When the campaign is ended every portion of the machine should be taken apart, cleaned, varnished, etc. This detail is too frequently neglected in beet-sugar factories and certain complications follow that need not be discussed for the present.

**Knife of blade holders.**—In the beet slicers formerly used the knives or blades were firmly attached to the revolving disk of the apparatus by means of a screw, and their regulating and renewing was an operation that demanded time and experience. Blade holders or frames which may be compared to a plane overcome the difficulty. They were formerly attached beneath the disk by means of four screws. HOROWITZ * was the first to design and have constructed a disk in which the frames and blades were introduced from above and remained in position without the need of screws.

**The holder** is a narrow rectangular frame, with raised end borders and exactly fits in the openings of the disk arranged for the purpose. The new STOEPEL † slicing knives are held in irregular slanting parallelopiped boxes; the direction given to these is that in which the machine is moving. The knives are kept in position by a frame fixed at the lower part of the box, the shape being such that on the revolving plate of the slicer more than the usual number of knives may be placed. Between the narrow sides of the blade holder there are two movable strips, one holding the knife and the other being the counter blade. The length of the blade holder is about 330 mm. and the width of the knives is generally about 140 mm. Each holder receives two blades, one at the end of the other, representing a continuous cutting edge. In the large Austrian beet slicers the blade holders or frames are of considerable size and are intended for three knives, their width varying from 90 to 120 mm.

The construction of these frames varies greatly, new models and combinations being introduced every year. The essential condition for keeping the knives in position is that the holders be made of some hard substance that can resist considerable wear and tear. They should be solid and readily handled, having openings to allow the free passage of the cossettes. The combination should be such as to permit the blades to be placed in position with

* Z., 27, 770, 1877. † N. Z., 42, 211, 1899.

the greatest ease and in the least possible time, so that their cutting edge may have an exact height and be at a determined distance form the counter blade. The satisfactory placing of the counter blades offers very little difficulty, as their distance from the cutting knives is arranged to suit each special case. The frames with their knives should be so adjusted in the special openings of the disks as to be on an exact level with it, as the slightest projecting angle or border would destroy the ultimate satisfactory working of the slicer. Every projecting portion would knock against the beet, forcing it out of its exact position, and the poor slicing thus caused would necessarily result in very irregular cossettes, producing a sort of pasty mass. For this reason new blade-holding frames cannot always be used with old disks, as these always become worn through usage, and for the same reason old frames are not readily adjustable to new disks.

If all these conditions are complied with it does not much matter what the construction of the blade frames is. However, upon general principles it may be admitted that the simpler the more satisfactory will be the practical results ultimately obtained. Certain knife-holding frames are said to be superior to all others. So they may be in certain essentials meeting exceptional cases, but it remains to be ascertained whether all the requirements have been fulfilled. The knife holders when in position should all be concentric in arrangement, otherwise, as previously pointed out, the resulting cossettes would be very irregular in shape. An excellent suggestion has been made by URBANEK * to have the frame holders all numbered so that each may be returned to its respective position after the blades have been renewed or adjusted. Owing to the difference in velocity of the slicing blades on the revolving plates, the wear and tear differs according to their position, the result being that the cossettes are not all of exactly the same size. A simple wedge attachment, which after it has been properly adjusted, is held in position by special bolts, is said to overcome this difficulty in a measure.

**Counter blade.**—The counter blade is supposed to continue the surface of the disk until meeting within a fraction the edge of the knives. In most cases its upper surface is upon the same level as the surface of the disk. Frequently it is found desirable to slightly raise the counter blade in front of the knife so that

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* B. Z., 9, 12, 1884.

the beet will be pressed against the former, but this arrangement is objectionable in that there is always a tendency for the beet to move when coming in contact with the blades which results in irregularly shaped cossettes. The wear and tear of the blades may in a measure be compensated for by the counter blades by advancing them when the knives are worn down, so that the spacing between the two remains nearly constant. In most cases the counter blade is stationary and it is the knife itself that is moved, being made to pivot around one of its sides by pressing small screws or bolts underneath. The counter blade is raised in many different ways. It is frequently rounded underneath, resting upon a socket of the same shape, and has, in such cases, a pin that enters a mortice of the socket. Under these conditions it may be made to swing as desired, and is held in position by suitable gudgeons. The arrangement of the VORSTER * counter blade is shown herewith (Fig. 63). The counter blade may also

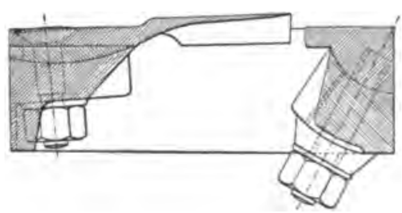

FIG. 63.—VORSTER Rotating Blade with Counter Blade.

have two screw-top holes at its extremities which may be displaced by sliding in two grooves on the sides of the knife holders Two screws also penetrate the sides, but from top to bottom, and by turning these in one direction or the other the counter blade is raised or lowered. However, as these are parallel motions it follows that the counter blade frequently extends over the disk on the side where it touches, and there necessarily follows a shock on hitting the beet which would tend to destroy the grooves made upon its surface by the passage of a previous knife. The arrangement described above needs no tightening screws to keep the piece in position; it permits a rapid adjusting and is mainly used for regulating the height of the slicing knives. In order to prevent the shock and to keep the surface of the blades on the same level as the disk of the slicer, the EBERHARDT † counter blade

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* Z., 52, 1036, 1902. † D. Z. I., 24, 295, 1899.

passes over the exterior of the blade holder and becomes a sort of inclined plane resting upon the disk, or passes into special grooves in the open spaces of the disk intended for the blade holders. This inclined plane holds the knife so that whatever be the height given to the counter blade it is always relatively in the same position in regard to the disk; even when raised vertically in order to change the height of the knives the angle formed by the counter blade with the blade itself is not changed.

The spacing between the counter blade and the knives is very rarely regulated by the counter blade. Experience shows that it is far better to displace the knife, although with some double blades it is necessary to approach or space the counter blade. Owing to the difference of rotation at the centre and at the outer border of the disk, the counter blade will wear very much more at the extremity near the periphery than at the other end, and this naturally tends to produce cossettes of entirely different sizes at the two extremities. The mathematical adjusting of the knives seems to be out of the question in such cases, but a wedge may be placed under the counter blade, thus compensating for the wear. When once adjusted the wedge may be kept in place by suitable bolts, which is an easy way of overcoming the difficulty to a moderate extent. Unfortunately, as the blade holders frequently wear in the centre and as the disks show the same worn-out portion, the cossettes are thicker at the centre of the frame. To replace the counter blade would not overcome the difficulty and the entire disk must be freshly planed, subsequently using thinner counter blades. The PUTSCH * counter blade is made up of two plates, one over the other, the upper one being rather thin tempered steel. STOECKER claims that by ridging the counter blade as well as the disk in the same manner as the knives are ridged, the beets are well guided and do not move during the slicing.

**Counter blade stone remover.**—When handling very fibrous beets and also when small stones are introduced into the slicer with the roots, one may use counter blade stone removers (Fig. 64) to considerable advantage. Their posterior sides do not extend the entire length of the blade, but have the same ridged edge as the knife. Only a few thin points advance near to the knives. The fibres and especially the small stones become wedged and pass through the opening left in front of the blades.

* N. Z., 30, 275, 1893.

The counter blade that precedes the PUTSCH * knife has ridges which act as gutters, corresponding to the ridged portion of the knives, the idea being to permit the small stones and sand to escape without damaging the blades with which they would otherwise come in contact.

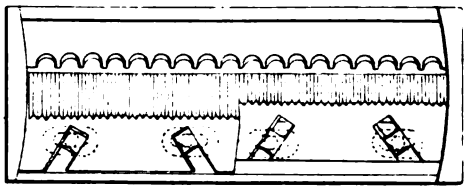

FIG. 64.—Counter Blade Stone Eliminator.

**Blade carriers.**—In some exceptional cases the blades are attached to a fixed band on the knife holders, and when this method is adopted the counter blade may be regulated, but generally the knives may be displaced front or back upon their support. Experience shows that this transverse bar should have a triangular section so that the cossettes will not break when coming in contact with its otherwise flat surface. As far as possible it is desirable that the oblique surface thus made be a prolongation of the bottom of the knive ridges. Efforts have been made to make this transverse bar as small as possible by resting the knives upon their holders. This mode, however, is seldom used.

In the STOECKER, as well as the PUTSCH (Fig. 65) blade holder,

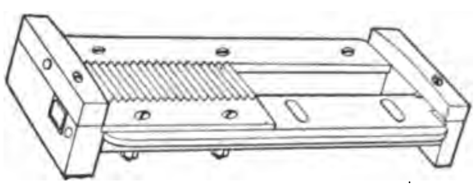

FIG. 65.—PUTSCH Dovetail Extremity Blade Holder.

the knives have dovetail extremities and are movable in vertical grooves by which they are guided when their up or down position is changed. The motion is obtained by means of two double-headed screws, one at either extremity of the blade, which are placed one above and the other beneath. The height of the knives may thus be rapidly regulated. In another of PUTSCH's blade holders the

* Z., 51, 374, 1901.

knives swing just as was previously described in the case of the counter blades, and, in fact, it may upon general principle be admitted that all modes used for regulating the counter blades may also be applied to the knives.

**Fixation of the knives.**—Slicing knives are generally held in position by being screwed or bolted to the upper surface of the cross bar, although in the STOEPEL * mode they are attached underneath. In most cases the knives are held by two bolts with their nuts well buried in the cross bar. The mortices are generally elongated in the direction that the knife slices so that the blades may be advanced as their edges are worn. However, this arrangement has several disadvantages; among others the cross bar must be exceptionally wide, though it need not be so wide if the mortices are lengthwise. In the latter case, however, the heads of the nuts cannot enter holes of the same size as in the former case, but oblique openings will permit the knives to slide in any desired direction (Fig. 64), and thus permit the blade to be used under economical conditions. The illustration shows on the one hand a fresh blade and on the other a blade half worn down. The last-mentioned method is very little in vogue.

Finally, there is a type of knife holder (Fig. 66) in which

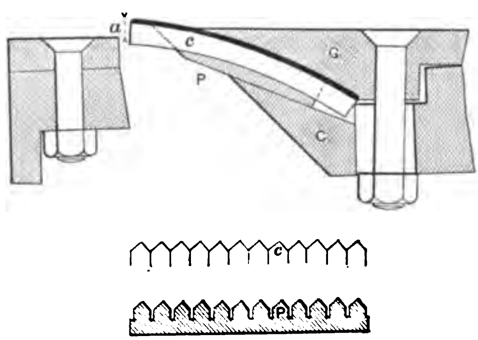


FIG. 66.—Two-piece Cross Bar with Ridged Surface.

the cross bar consists of two pieces, *P* and *G*, between which the knives are held in position. In this case the knives have flat backs and may be sharpened over their entire length. The plates holding the knives may be smooth, but they will then not hold the blades sufficiently tight. It is better to give the plates the

* Z., 50, 849, 1900.

same surface as the knives, as shown in Fig. 66. To more thoroughly guide the beets the upper surface of the holding plates is fluted, *G*, and has the same divisions as the knives. However, this fluting on the inner surface of the holders has this disadvantage, that it allows only one type of knife to be used, having exactly the same number of divisions.

**Diffusion slicing knives or blades.**—The diffusion slicing knife consists of a blade fixed in a holder just as a reversed plane would

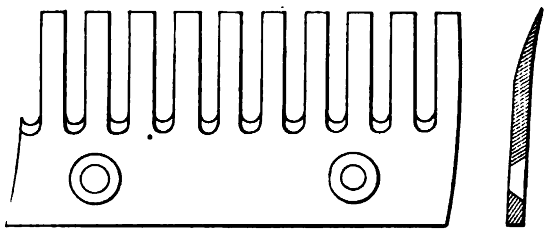

FIG. 67.—ROBERT Slicing Blade.

be. Sometimes the holder contains two knives with different cutting edges which are called double knives. If the blade were a plane surface it would simply give flat beet slices.

The knives or blades used in small beet slicers for the production of cossettes are always 140 mm. in length, the width depending upon the box while the thickness varies from 7 to 9 mm.

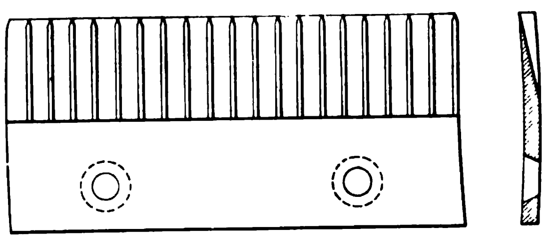

FIG. 68.—NAPRAVIL Slicing Blade.

The first cutting blade used for beet slices (Fig. 67) was in connection with the ROBERT * diffusion apparatus. It was flat, but the edge had certain interstices, very like a large comb, and the blades followed each other in the slicer so that the teeth of one covered the spacing of the other. These teeth cut the beet into long rectangular strips, which give a considerable sur-

* N. Z., 2, 388, 1879.

face for sugar extraction, but the strips are too large, and in consequence these blades are used only in exceptional cases. The NAPRAVIL beet-slicing knife is a decided improvement. It consists of a flat blade with raised surfaces perpendicular to the cutting edge. The flat portion of the blade cuts the beet into slices and the raised portions cut these into rectangular strips. It is to be noted that the ROBERT knife, which may be called a semi-slicing knife, cannot give slices or strips in the entire length of the knives, but leaves grooves which the succeeding knife removes. The NAPRAVIL knife, on the contrary, gives a full and complete slice. The semi-slicing type of blade has not a continuous cutting surface above the counter blade, either because there are certain intervening spaces, as in the ROBERT blade, or because it is partly hidden by the counter blade, as in the KOENIGSFELD knife, which will be described later. On the other hand, in the full cutting knives the slice is cut in a continuous line. The cossettes obtained by the NAPRAVIL blade give considerable exposed surface, on which the water in the diffusion battery can have ample osmotic action.

But progress along other lines in the slicing blades demanded still further improvements. In certain countries, Austria for example, the mode of taxing the beets sliced compelled changes

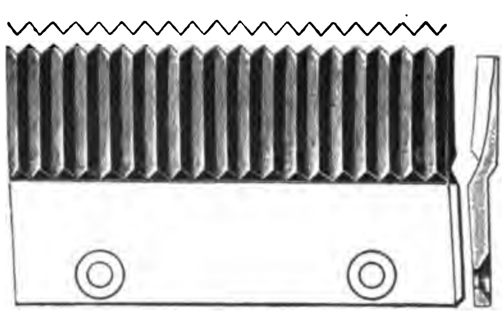

FIG. 69.—KOENIGSFELD Blade.

which are evidently to the advantage of the manufacturer. The KOENIGSFELD *slicing* blades were first brought to notice in 1875 by EGERLE, but he never used them practically. It was GOLLER and KOENIGSFELD (Fig. 69) in Austria who made them a decided success. The blades have a zigzag cutting edge, the lower points being beneath the counter blades. By this arrangement small acute angles pass above the counter blades, which make a series

of triangular grooves in the beet. This knife, like others belonging to the semi-slicing category, is followed by another blade, the shape of which is such as to remove all the first blade has left. The first cossettes of the series are nearly triangular, those of the second series are as shown in *d* (Fig. 70), followed by those like *e*, which are reduced in size by the first slice, and thereafter all the slices are ∧ shaped.

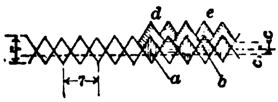


FIG. 70.

With the KOENIGSFELD blade all the cutting portions of one series should correspond to the gutters of the other, but this condition is never realized. This explains why there will be certain cossettes in the form of the gutters or grooves, which are in the majority, while after one continuous slicing the shapes may be more variable and of endless profiles. Fig. 71 and Fig. 72 show another combination and the sections of the resulting cossettes. The KOENIGSFELD knives are made by cutting a plate of steel down to a fine edge or by stamping a sheet of steel.

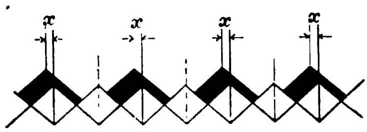


FIG. 71.

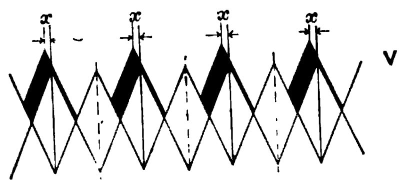


FIG. 72.

**The angles made by the knives** have a most important influence upon the general working of the slicer. The more acute the angles of the ridge and the closer they are together the greater will be the danger of clogging by the fibrous portions of the beet. However, there are important advantages in having these angles relatively small, as the cossettes thus obtained will not so readily pack in the diffusor of the battery as they will when the angle is more open. KARLIK recommends that the proportions for these angles be 6 mm. in width and 4.3 mm. in height. However, the sizes generally used correspond to an equilateral triangle with angles of 60° each. According to the width of the divisions, or the width one wishes to give, the size of the angles will vary as follows:

| | |
|---|---|
| 3 mm. wide | 2.60 mm. high |
| 3.5 mm. " | 3.03 mm. " |
| 4.0 mm. " | 3.46 mm. " |
| 5.0 mm. " | 4.33 mm. " |
| 6.0 mm. " | 5.20 mm. " |
| 7.0 mm. " | 6.06 mm. " |
| 8.0 mm. " | 6.93 mm. " |

In some beet-sugar factories a preference seems to be given to knives with rather wide ridges. Karlik recommends the wide divisions as giving more regular cossettes for if one of the knives is displaced 1 mm. from its lateral position in relation to the knife that follows it is still possible to obtain grooved cossettes of a regular shape, while this is impossible of realization with knives of very acute angular divisions. In the case of narrow divisions it is absolutely necessary that their construction and their position on the disk be mathematically exact. An excellent example is shown in Fig. 71, where with wide division and a displacement the cossette still remain more or less regular, while in Fig. 72, with narrow spacing and a displacement it is very irregular. One of the main disadvantages of the Koenigsfeld blades is their comparatively limited efficiency. On the other hand, they may be sharpened more rapidly and do not become so readily clogged with fibre as do the standard ridge blades.

**The ridge blade** also may be said to have been invented by Egerle. It differs from the Koenigsfeld knives in the fact that the lower angles are also sharpened, while the last mentioned blade, if it were placed entirely above the counter blade, would give zig-zag cossettes. The ridge knives, owing to their double edge, will give at once a series of cossettes that are ▲ shaped (Fig. 73), and consequently there can be no possible advantage in placing these knives below the counter blade. They should, on the contrary, be placed well above, the height depending upon the thickness of the cossette one wishes to obtain. The knives in question are of the full slicing variety and continuous in their action above the disk. The first knives give cossettes of *a* shape (Fig. 74), and these are followed by those like *b*. This mode of slicing is shown in Fig. 75. These blades, as may be readily imagined, have a greater cutting efficiency than those previously mentioned, but when slicing annual beets, which are exceptionally fibrous, they become very much clogged, more so

than do the KOENIGSFELD knives. By increasing the opening of the angle of the ridge the difficulty may in a measure be overcome.

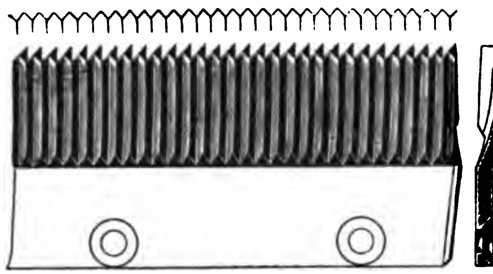

FIG. 73.—Ridge Blade.

Its upper angle varies from 84° to 120°. As a general thing preference is given to an obtuse angle, which offers many advantages.

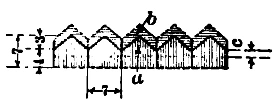


FIG. 74.

First of all the cossettes free themselves much more readily, and, furthermore, a slight displacement of the knives and their frames means less variation in the shape of the resulting cossettes than would otherwise be the case. The sharpening of the knives is also more readily accomplished, but notwithstanding this fact great care should be taken in adjusting them on the disk. HULLA *

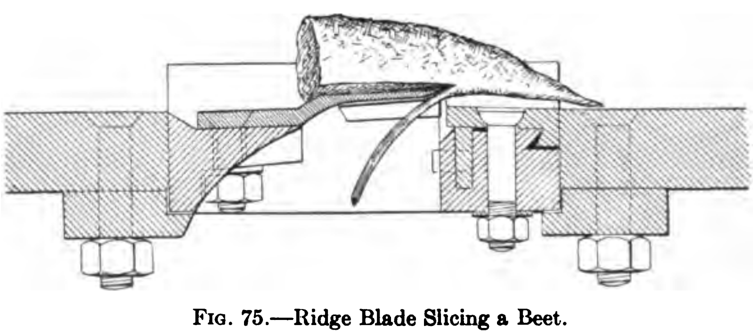

FIG. 75.—Ridge Blade Slicing a Beet.

proposes to alternate the KOENIGSFELD with the ridge blade. The ridges of these knives are cut into plates of steel. In Russia special importance is attached to the length of the second edge. An excessive length permits one to keep the knives well away from the

* Oe.-U. Z., 18, 483, 1889.

counter blades, and, as in that country the beets are frequently fibrous, a precautionary measure of this kind prevents any abnormal clogging.

The grooves of these knives are generally more or less arched and concentric to the axis of the disk. Other knives, however, give perfectly straight grooves, tangent to concentric circles of the disk, the axis of which is taken as a centre. In theory this is interesting, but in practice the circle passing at the middle of the knives is taken as a type for the arches of all groves.

**Knives for frozen beets.**—When beets are very ligneous when they are frozen, or even when they are soft after thawing, great difficulty is generally experienced in obtaining regular beet slices. In most cases effort is made to use either the KOENIGSFELD or ridge knives with very wide divisions, but frequently these will not work. One is then obliged to resort to the ROBERT finger or forked shaped knives, but as the resulting cossettes give very little surface contact with the water circulating in the diffusion battery the special PUTSCH blades (Fig. 76) must be used. It is recom-

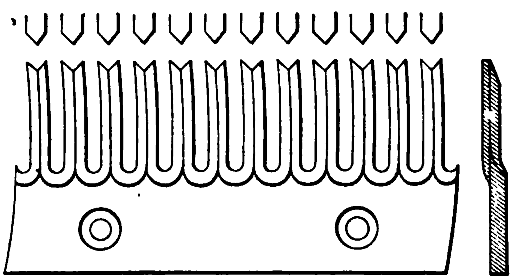

FIG. 76.—Blade for Frozen and Ligneous Beets.

mended that ligneous beets be cut with the so-called finger knives, but that their edges be ridged. The triangular shape of the resulting slices is obtained by having the lower part of the ridge continued vertically, as in the case of the standard ridge knives.* Besides the types of these special slicing blades mentioned in the foregoing there are numerous others, but as they have never been generally introduced a description of them would be of but secondary interest.

**Double slicing knives.**—The double knives do not give grooved cossettes as obtained either by the ridge or KOENIGSFELD blades, but it must be noted that with the two last the average shape of

* D. Z. I., 24, 1009, 1899.

the cossettes, when considered collectively, is not up to the standard demanded by theory. As experience shows that the diffusion battery works to the best advantage only when the slices are uniform and regular the double knives giving triangular cossettes have been popular. These knives are bolted in such a way as to have a blade with a ridge edge followed by a blade with a plain edge. The first knife gives a cossette with a triangular section, and the plain-edge blade cuts the beet where the section was removed, also giving triangular cossettes. These results appear to be more satisfactory than are realized with most of the known types of slicing knives. From the standpoint of practical working in the diffusion battery, however, the triangular cossettes do not give the same satisfactory results as do the gutter-shaped slices obtained with ridged knives.

The first double knife used, which consisted of two Koenigsfeld blades following each other, was invented by Weyer.* The results obtained were not up to expectations and the idea of producing hollow cossettes was abandoned. The first Bergreen knife consisted of a blade on the Koenigsfeld order immediately followed by a flat knife. The first cossette obtained was ▲ shaped, the next was shaped thus ▼; after the passage of the flat knife the beet had a flat surface. The same changes were repeated as soon as the slicing operation commenced. While these knives have never been in general use they may give satisfactory results in overcoming the difficulties presented by frozen beets.

The double-knife Bergreen slicer has undergone some changes since its introduction. The cossettes first produced would frequently stick together,† which destroyed the object in view, i.e., the production of beet shavings or slices offering the greatest facilities for osmotic action in the diffusor. Behind the first knife there were placed small arrestors that sliced in two the cossettes made by the regular blade, and still better results were realized by using, instead of a flat knife, a Napravil blade, the ribs of which corresponded to the hollows of the preceding knife. If it were practicable to follow the Koenigsfeld (Fig. 77) blade immediately by a plane knife it would then be possible always to obtain regular cossettes. Unfortunately when the spacing between the knives is not sufficient the open space left between the blades intended to allow the slices to pass through becomes clogged, and under these

* Revue Univ. F. Sachs, 1883–1884, p. 36.

† N. Z., 42, 42, 1899.

circumstances if the first knife breaks the second blade breaks also. BERGREEN lengthens the back of the blade so as to extend beyond the ridge, and uses this portion as a counter blade for the knife that follows. It is possible to have a sort of screw attachment to the binding strip holding the first blade and a narrow counter blade, the height of which may be exactly adjusted to the work to be done. The distance between the counter blade and the second knife may be regulated just as it was in the first case mentioned in the foregoing.

The first of these blades is ridged so that the beet presents itself in the most desirable position in front of the second knife.*

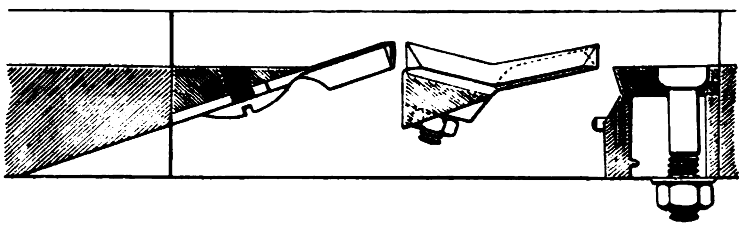

FIG. 77.—Position of the Double Slicing Blades.

It is bent on its entire length so as to form a counter blade for the second knife, the arrangement being such as to offer the same profile as the slicing edge in front. Under these circumstances the beet is tightly held at the moment the second blade does its slicing.

To prevent the second blade of a double slicing apparatus from being broken or damaged by small stones or like obstructions, HILLEBRAND † has proposed that a portion only of the back ridges shall project toward the second knife. These projections alone are sufficient to guide the beet, but between them is so much space that all the hard substances escape. On the back of the blade are grooves in which are placed the tightening screws; as they are applied upon inclined planes it becomes possible by sliding them backward or forward to modify the height of the blade at will. The main difficulty contended in the double-blade mode of slicing is the knife regulation. In most cases the knives have a position in which the height cannot be changed, so the counter blade is raised and the second knife is lowered, keeping its cutting edge at the height of the upper portion of the top knife.

In the STOECKER ‡ blade the movable rods supporting the two

* Z., 52, 266, 1902. † Z., 52, 275, 1902. ‡ Z., 53, 96, 1903.

knives are held together by cross bars which permits them to be raised at the same time that their height is regulated.

**Quality of the cossettes.**—The entire success of extracting the sugar contained in beet cells depends upon the quality of the cossettes. The beet slices obtained by the KOENIGSFELD or the ridge knives should be long, clean cut, and as thin as possible without reaching a condition in which they could not hold their own when submitted to the pressure of their own weight; they should be uniform throughout, not containing any ends of roots or pasty compounds. CLAASSEN emphasizes the fact that to obtain satisfactory cossettes the beets must be properly washed and the roots freed from small stones, etc., before reaching the slicer. It would be advisable in most cases, when the beet slicer is found to work irregularly, to change the washing appliances and substitute the large modern receptacles rather than to conduct a series of experiments with new types of blades and frames. Without doubt superior cossettes are one of the essential conditions for the proper working of a diffusion battery, and for this reason the cost of a new beet washer is soon covered by the increased efficiency of several of the machines that follow in the various stages of sugar extraction. It is difficult to decide which one of the three types of blades mentioned to recommend, as each has its advantages and disadvantages. Without doubt it is possible to obtain very satisfactory results with all three of the typical blades if the knives are well tempered and frequently sharpened and placed carefully, not only in their respective frames, but also upon the revolving disk in a position exactly opposite to their counter blade, as has been explained. These conditions are theoretically feasible, but there are numerous difficulties to be overcome. In practice one must be content to have one-fourth of the cossettes of about normal shape and size, and according to PASCHEN 30 per cent is never exceeded. The causes of the irregularity in the cossettes are numerous, among the principal ones may be mentioned the following: First, the beets at their periphery rarely cover an entire division of the edge of the knife, giving half slices and frequently less; second, the knives may be of different makes, having the divisions of their ridges greater in one case than in another; third, if the height of the knives is different it has considerable effect, especially with the KOENIGSFELD blades, and if this is the outcome of the wearing away of the counter blades, cossettes thicker at the centre will be obtained; fourth, the knives and their frames or holders may be placed eccentrically

one to the other, in which case their faults will not correspond.

The importance of placing all the grooves exactly one behind the other, or one behind the middle of the other, is apparent from the accompanying diagrams (Figs. 78, 79, 80), showing the sections of the cossettes obtained. When the difference is very slight, as in Fig. 78, they are very nearly normal, but when the difference is greater the sections are as shown in Fig. 80, they are far from what was intended. Fig 79 gives an average between the extremes. The extent to which poor cossettes may be obtained when the con-

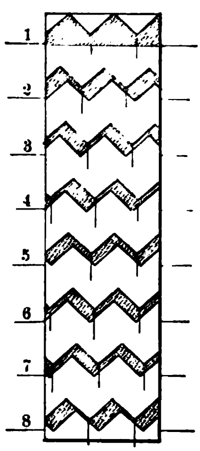


FIG. 78.

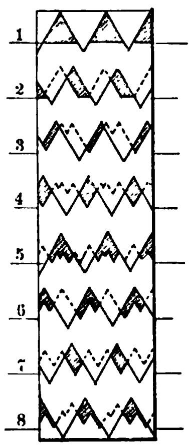


FIG. 79.

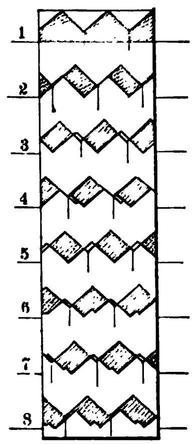


FIG. 80.

ditions are unfavorable is shown by HULLA* in the following diagram. The experiments were made with GOLLER slicing knives, whose divisions did not correspond and which, furthermore, were badly adjusted. The blades are supposed to be slicing two beets that are side by side (Fig. 81), their positions being shown by the dotted lines, while the shaded portions represent the sections of the cossettes obtained. A glance at this diagram shows that very few of the cossettes are normal in shape. Another very important cause of this result is that most beets change position during slicing, and to this must be added numerous accidental causes, such as clogging of the knives and their wear and tear. When all these facts are taken into consideration it will be seen that what has been said in

* Oe.-U. Z., 18, 481, 1889.

regard to the percentage of normal cossettes obtained is certainly not an exaggeration. Hence beet slicers should be most carefully examined, the adjusting of the blade holders and the sharpening of the knives being repeatedly effected. A certain control may be kept upon the quality of the cossettes by closely examining a handful taken at hazard from time to time, and also by the CASTEEL * mode of classifying them in short and long slices after the sample

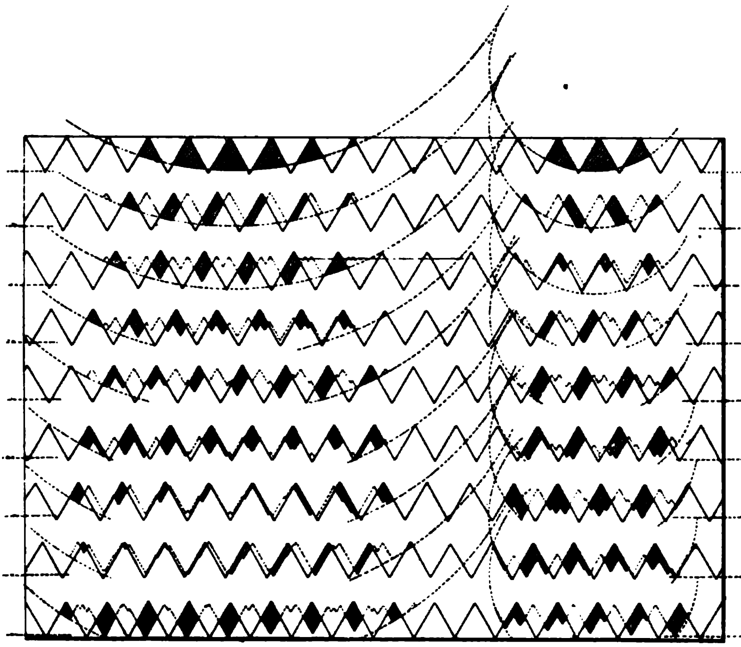

FIG. 81.—Diagram showing the Irregularity of Cossettes.

is obtained. When these slices are placed end to end 1 meter of the short ones should weigh about the same as 1 meter of the long ones. According to this authority the average weight of 1 meter of cossettes, allowing for different heights and spacing of the knives, should be as given in the following table.

CASTEEL contends that some weights for this standard length are more desirable than others, this evidently depending upon the manner of working the battery, etc. For example, the thicker the cossettes the less complete will the exhaustion be in the battery, while, on the other hand, as they have fewer broken or

* B. As. Belge, 5, 324, 1892.

TESTING THE QUALITY OF COSSETTES BY THEIR WEIGHT.

| Spacing of Knives. | Height of Knives. | Weight per Meter of Cossettes. |
|---|---|---|
| mm. | mm. | grams. |
| 2.0 | 2.5 | 6.820 |
| 2.0 | 3.0 | 7.100 |
| 2.0 | 3.5 | 8.940 |
| 2.5 | 2.5 | 7.010 |
| 2.5 | 3.0 | 7.970 |
| 2.5 | 3.5 | 9.150 |
| 3.0 | 3.0 | 10.500 |
| 3.0 | 3.5 | 11.300 |

cut cells for a given section the juice they give will be purer, as will be shown under another caption. The standard of length necessarily depends upon the variety and size of the beets. Some years the roots are longer than in others, and evidently with small beets the slices are necessarily short.

**Slicing-blade division.**—The size of the cossette depends upon the number of ridges or divisions on the cutting edge of the blades and, consequently, upon the angles formed. The greater their number the finer will be the resulting beet slice. This close division is mainly for beets that are readily cut, while for frozen beets wide spacing is preferable.

The number of divisions vary from 20 to 40 per knife so that the ridges have a spacing of from 3½ to 7 mm. However, with the KOENIGSFELD knives it frequently reaches 8 mm., and for frozen beets the spacing may be 10 mm. During an active campaign it is frequently found desirable to vary the knives, the finer cuts being used in the beginning and the coarser ones toward the end when the siloed beets are being handled.

**Knife regulation.**—As the thickness of the cossette depends upon the height of the slicing knife above its counter blade, this should be regulated so as to produce the cossette best suited to the special requirements. A certain spacing is evidently necessary to allow the cossette to pass through. This must not be too wide, otherwise when the knives reach the end of the beet the slice obtained acts as a lever and tears off a portion of the beet, which then escapes without having been reduced in size by the slicing blade, resulting in what are known as combs, the cossettes being connected by an uncut surface.

The width and height of the cossettes obtained should be exactly the same, as all the blades on the circular disk are regulated with suitable calipers from 1 to 5 mm. in thickness. The blade being temporarily attached to its cross bar the caliper is placed between it and the counter blade, and the knife is brought down to press hard against the surface of the caliper, which is then placed on the counter blade so as to regulate its height, being raised or lowered, as the case may be, until the ridges of the blade are distinctly felt by passing the hand on the upper side of the caliper. This mode of regulation is very simple and offers all the advantages of a more complicated appliance. In regulating the ridged type of knives it should be remembered that a displacement in the height of one-half a millimeter will give large cossettes; hence these knives must be regulated with exceptional care. The adjustment of the KOENIGSFELD knives is less complicated and offers no difficulty. According to HULLA * the most desirable height for these knives is 1 mm. below the counter blade. If the latter is in the least worn the cossettes will vary in thickness. The spacing between the blades in the frames, which generally are arranged to hold two blades, varies very much in different countries. In order to regulate the knives properly it is important that the blade be properly constructed in every detail, that its shape be normal, that it be well made and of the best material. The MOREAU † caliper (Fig. 82) enables one to

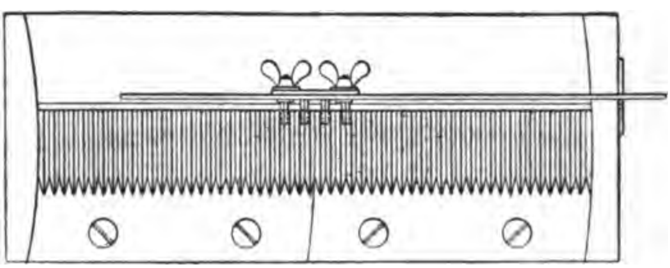

FIG. 82.—MOREAU Caliper.

ascertain whether the ridges of the same or different blades comply with the desired standard. This caliper consists of a metallic square, the short side of which is placed against one of the shorter ends of the blade holder, while on the longer side there glides an index with four standard marks indicating exactly where the

* Oe.-U. Z., **18**, 481, 1889. † B. As., **16**, 677, 1899.

ridges should commence and end. This index is placed on top of the knives and into the existing ridges and is then tightly screwed onto the square. It is evident that when the caliper is placed in the knives in another frame it will at once be apparent whether they have the same position or not, and they can then be adjusted accordingly.

**Slicing-blade sharpening.**—The life of a slicing blade is very variable. When the beets are normal it may work under satisfactory conditions for ten hours, while if the beets are of poor quality or have not been properly washed the blade must be renewed after an hour, and this difficulty is even greater when the roots are fibrous or retain particles of straw from the silos. The fibre straddles the edge of the blade and necessarily destroys its slicing power. Under these conditions the knives must be renewed every half hour unless they are cleaned without being removed from their position, which may be done with a thin chisel and hammer. The better plan is to submit the knives to a thorough washing and scrubbing after their removal from the frames, though it involves more work, but as the slicer is stopped only for a few minutes its total working capacity is not materially altered, and the cutting edge of the knife lasts very much longer without being resharpened. The brushing appliance previously mentioned can render great service in such cases, as there need then be no stoppage. It is customary in many factories to renew the knives at hours fixed upon in advance. This idea is evidently a mistake, for while the roots may be very poor during most of the time when they are of satisfactory quality the slicing might continue for four hours and yet the cossettes conform in every respect to the desired standard. The superintendent of the factory, the man in charge of the diffusion battery, etc., should give all their attention to the regularity of the slicer's working, and as soon as the cossettes are not of the desired shape, they should insist that the blades be changed. Worn or broken edges must be resharpened. In most cases this resharpening is done simply by hand filing, while in other cases it is accomplished mechanically with machines specially constructed for the purpose, or else by machine followed by hand filing. The knives must be removed from their frames, which should be well brushed, washed and dried. Even if the edge is not broken it may frequently be desirable to plane it down so as to make sure that it is straight, and then sharpen. In general this planing simply means filing, but it is more rapidly

accomplished on a grindstone (Fig. 83). It should be done with care so as not to destroy the temper of the blade and so that the cutting edge remains parallel with the back of the knife, other-

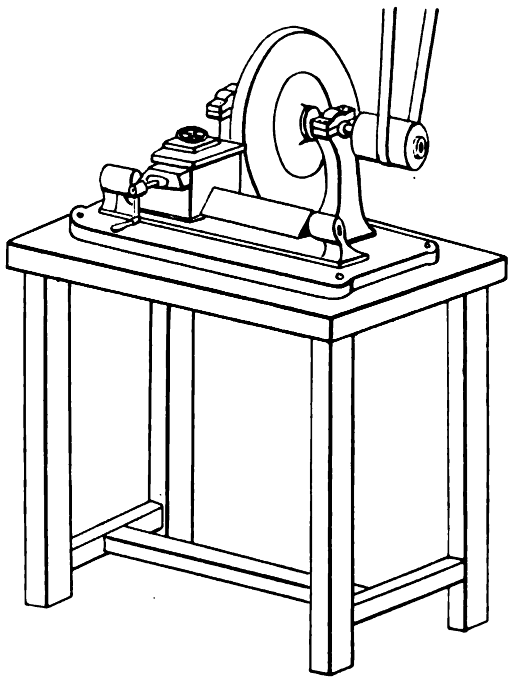

FIG. 83.—Grindstone for Slicing Blades.

wise certain difficulties will arise when the blades are placed in position. A small, simple device (Fig. 84) consisting of two plates sliding parallel, one on the other, is used as a caliper. The flat surface of the knife is placed on *A* and the back rests on *B*. One plate slides on the other until the edge of the blade corresponds to the top of *A*. There should be an absolute accord because the sides of *A* and *B* are absolutely parallel. Certain factories plane their knives, not in a direction perpendicular to the sides of the ridges, but slightly slanting, forming a bevel, and thereby lessening the clogging. The height of the ridge is necessarily reduced after each sharpening and when its length is diminished by 15 mm. it is out of service and beyond

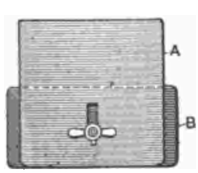


FIG. 84.

repair, as the obtuse angle at the bottom of the grooves would break the cossettes.

**Hardness of the steel blades.**—This point has an important bearing upon the life of the knife and upon its sharpening. For beets that are mixed with sand, small stones, etc., softer steel is used than for well cleaned roots with which there is less danger of breakage. The hard, steel knives are more difficult to sharpen, but when once ready they last much longer. Formerly before slicing blades were sharpened they were distempered. Sharpening with files was practiced only after the blades had been heated and allowed to cool slowly in order to be distempered. After filing they were tempered again carefully. These manipulations were most difficult. The dipping generally deformed the blades and the edge had to be repolished in order to obtain a smooth, clean cut. To-day moderately soft steel is generally used and it is sharpened more frequently. Hand sharpening is done with small, square, triangular and rectangular files, and while not difficult it demands experience and is too frequently neglected. The cutting edge should be fine and regular and the bevel as long as possible. In most cases the grooves are elongated to about 20 mm., and when the actual cutting edge is reached the angle is made more obtuse and well sharpened, having a length of from 1 to 1.5 mm. This cutting portion holds its own for a considerable time. When beets are on the disk of the slicer their surface is brought horizontally in contact with the slicing knives. The bevel that is to do the cutting should also be horizontal and may be obtained with most of the existing blades which are attached to their cross-bars with bolts. On the other hand, when the knives are held in position by jaws certain difficulties arise. The angle of the blade is added to that of the bevel and the edge of the knife scrapes rather than slices the beet. A certain filing of the upper edge must then be resorted to so as to bring its surface parallel with that of the disk. In a special HILLEBRAND blade this difficulty is said to be overcome by centering the knife in the direction of the attachments. It is claimed that the cutting blade is then very nearly horizontal on the edge where the slicing commences.

**Mechanical sharpening** may be satisfactorily accomplished by exactly imitating the hand filing. This is very cleverly accomplished in the LEHNARTZ apparatus shown in Fig. 85. The blade is held by the screw grips *j*, and the file is held tightly in the jaws *d*. The up and down motion is obtained by the arm *c*, which is

worked from the shaft *b*, either turned by hand or with a system of belting directly upon the pulley. In most cases the sharpeners are

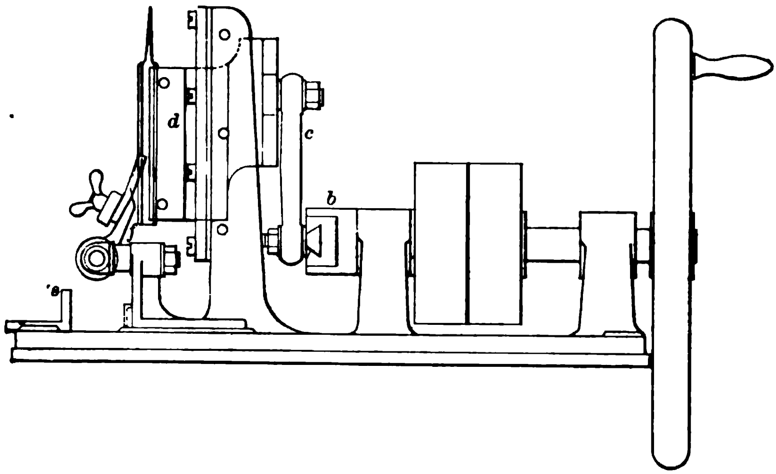


FIG. 85.—LEHNARTZ Mechanical Filer.

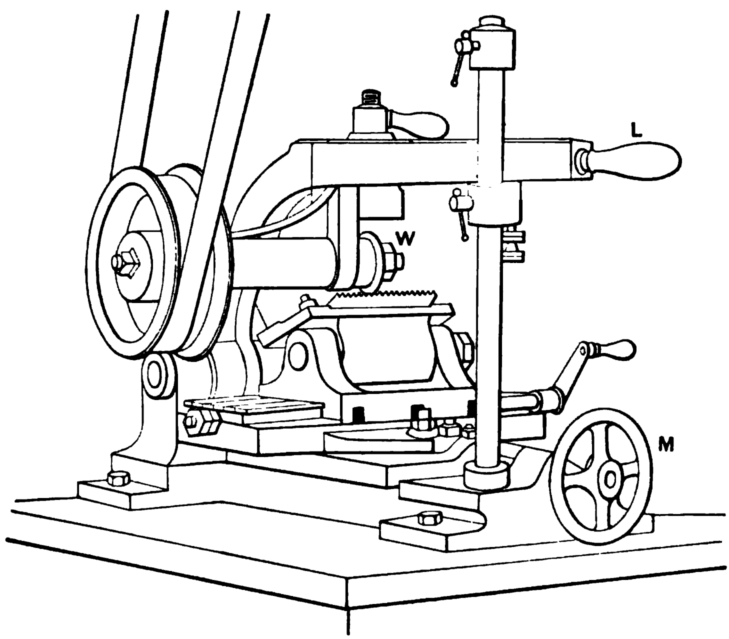


FIG. 86.—Multiple-movement Sharpener.

simply chromated, corundum or carborandum wheels. The drawing (Fig. 86) shows the blade attached in a suitable position and placed

at the desired angle. It may be moved backward or forward by turning the wheel $M$, and its angle may also be varied. The wheel $W$ is controlled by the handle $L$, the motion being received from a pulley. All portions of the ridges of the blades may be reached. In another type of machine shown in Fig. 87 the axis on which the grinding wheel revolves may be given an inclination to meet the requirements of the case and may be adopted to any type of blade and its ridges. Some pieces of mechanical apparatus do not

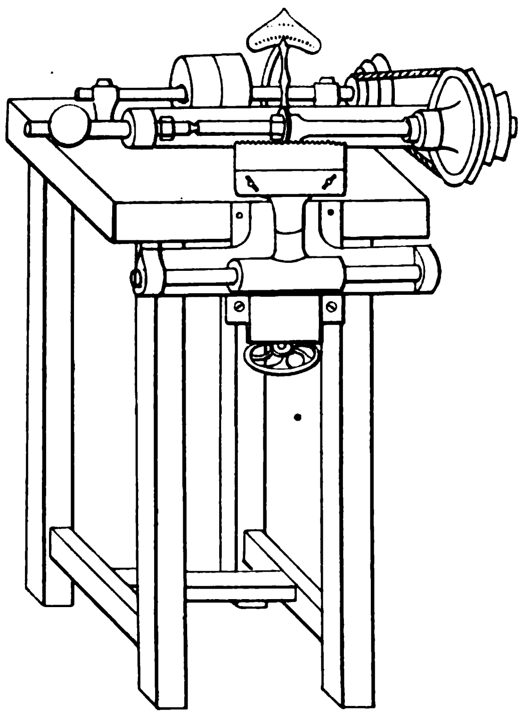

FIG. 87.—Grinding Wheel with Movable Axis.

need any attention when once set, and among them the PUTSCH * sharpener may be mentioned. Upon general principles the sharpening demands constant and careful attention, because it frequently happens that it is desired to push the work just to that limit when very little filing is needed for finishing. Complete mechanical sharpening necessitates a special combination for every variety of blade that may be used. Do what one may the complete automatic sharpening is always defective and has very weak features,

* N. Z., 9, 182, 1882.

for example, the blades are frequently not mathematically correct in their construction, or are put out of shape during mechanical sharpening. PELIKAU met with some success by using a very strong steel die, in which the blades, after being heated to the desired temperature, are pressed and thus made to assume their original shape. The emery or metallic wheels used in this case are made to revolve so that the resulting sparks will not be thrown into the eyes of the workman. This is accomplished by working in the opposite direction to that of the sharpened edge, but the reverse is the case when filing. The sharpening is always done by the dry method, the mode of working depending upon whether or not it is the intention to temper.

Among the rough modes of blade sharpening may be mentioned that of STANEK,* in which the carborandum wheel used turns at the rate of 1500 revolutions per minute. The blade becomes red hot and the rapid cooling that follows depends upon the distance between the sharpening wheel and the edge of the knife. This method results in a sort of tempering. Filing must necessarily follow, but this in reality simply means a scraping of the edge.

**Electrical sharpening.**—Some ten years since the electrical sharpening of diffusion blades was in vogue and applied also to the electrical sharpening of the files. The files had to undergo a preliminary preparation by the PERSONNE method. They were first washed in oxalic acid to remove the rust, and then with caustic soda and ordinary soda, and finally with clear water, before being placed in the electric bath. This bath consisted of a battery of which one pole was the carbon and the other the file itself. The diffusion files were placed in bronze handles and suspended in a glass receptacle containing a 3 per cent solution of sulphuric acid at 66° Bé, and a 6 per cent solution of nitric acid at 40° Bé. The glass jar had a copper cover which brought about a short circuit of the battery. After 30 minutes the resharpening was finished. The sharpening of slicing blades † may be accomplished in very much the same way, with the exception that they are not rusty or greasy and no preliminary cleaning is necessary. The blades are suspended in the bath so as to be as near as possible to the carbon. The sharpening lasts from 15 to 25 minutes and costs about one-half a cent per knife. Most authorities point out that electrical sharpening has very little practical value, as the finishing must always be done by hand, and the method has now become nearly obsolete.

* B. Z., **23**, 527, 1898–1899.

† B. As., **9**, 533, 1892.

# CHAPTER II.

## DIFFUSION.

**History.**—During the first part of the last century the methods of beet-sugar extraction were confined almost entirely to those depending upon hydraulic presses. However, almost from the time of ACHARD, efforts were made to introduce new processes, as it was realized that the extraction of the juice from the beet by such crude appliances as were then used could not possibly meet the requirements of an industry destined to revolutionize sugar manufacture. As early as 1821 MATHIEU DE DOMBASLE resorted to the dissolving properties of water to extract sugar from the beet. The beet slices were submitted to a high temperature in order to open and kill the cells, for it was argued that it would be impossible to extract sugar from living cells. The heated slices were piled into cylindrical reservoirs and over their surface very hot water was poured. The sweet liquor from the first reservoir was sent into a second, third, etc., the juice becoming richer and richer in sugar, and at last attaining such a degree of concentration that it could be submitted to epuration. However, notwithstanding the actual advantage of the method, then called masceration, it was temporarily abandoned because of its cost, owing to the price of fuel and extra labor, and the fact that the high temperature to which the juice was submitted in a measure transformed the tissues of the beet into soluble pectic compounds, which became part of the juice and added very considerably to the difficulties of epuration. The question was sufficiently interesting to lead to numerous other investigations which resulted in changes and ameliorations of the DOMBASLE conception, but most of these attempts were doomed to failure, and it was left for JULES ROBERT to render the idea practical. His process was in reality an entirely new departure. It was in 1864–65 that the original method, known as diffusion, was applied for the first time at the SEELOWITZ (Austria) beet-sugar fac-

tory, and not many years elapsed before it was generally adopted in all European beet-sugar factories, and the primitive hydraulic presses were abandoned.

**Principle of diffusion.**—Two liquids which will readily mix may, with care, be placed one upon the other, but as there exists a molecular attraction after a reasonable interval of time they will mix in the receptacle in which they were placed, and there will then remain but one perfectly homogeneous liquid, the two liquids having diffused one into the other, hence the term diffusion. The theory of the ROBERT conception was based mainly upon the principle of osmosis and was improperly called diffusion. The beet tissue is made up of a series of elongated cells containing the juice. According to WIESNER * these cells have a diameter varying from 0.014 mm. to 0.022 mm. and a length of from 0.054 mm. to 0.089 mm. KEYR's † measurements are almost the same. The tissue of these cells consists mainly of pectic substances and cellulose, forming a porous diaphragm. If water is placed on the outside there will be two liquids in the presence of one another and their tendency is to diffuse; but the pressure not being the same in both cases they cannot mix until the water from the exterior enters through the membrane and the saccharine juice from the interior of the cell passes to the exterior, when an equilibrium will be formed. Crystalloids, or those substances which crystallize readily, pass more rapidly than colloids, which do not crystallize. Sugar belongs to the first category. The saline substances dissolved in this sweet juice also find their way rapidly through the membrane. Among the colloids that are slow to penetrate are the albumin amides, etc. Consequently the problem consists in keeping back what would be an impurity difficult to eliminate and obtaining only a saccharine solution.

This method was once thought to be simply, as its name implies, an actual diffusion, but there must at the same time be a sort of washing. Even with very smooth cossettes there are many broken cells, and the finer the beet slices are the greater is their number. According to WIESNER, a certain number of cells are crushed or burst in the several layers. KEYR ‡ estimates that the number of cells thus torn amounts to 6.41 per cent of all cells of the beets handled.

When in contact with water for too long time and at a too high

* Z., 39 306, 1889. † Z., 28, 308, 1878. ‡ Z., 28, 313, 1878.

temperature the solid matter of which the cellular membrane of the cossettes consists, mainly peptic compounds and organic salts of lime and potash, are dissolved, involving trouble in the working of juices. During the operation of diffusion there are three simultaneous phenomena, viz.: (1) the displacement of the juice in the broken cells; (2) the dialysis of soluble compounds in the case of perfect cells; (3) the ultimate dissolving of the solid elements of the beet. While the first two phenomena, especially the dialysis, are desired as being essential to diffusion proper, the third is an objectionable and destructive action, which should be overcome as far as possible. Unfortunately, however, the principles which favor diffusion also facilitate the undesired action. The rapidity of the dialysis of sugar contained in the plant cells depends upon the temperature at which the operation is conducted, the dilution of the juices and the quality of the cossettes. The operation is much more complete when the work is done slowly, that is when the battery is run slowly but at a high temperature. Unfortunately, these conditions essentially favor the solution of the solid substances contained in the plant cells.

It is interesting to note that when the cell of the beet tissue is dead it still allows the passage of dissolved substances in one direction or another until the solutions on both sides of the membrane are the same. Rapid dialysis is especially desired, and in order to accomplish this under the best possible conditions it becomes important to destroy or kill the protoplasms by heat; hence the advantage of heating the first diffusors of the series. Practical experiments have long since demonstrated that the rapidity of dialysis varies with the substance and with different solutions of the same substance; it increases with the concentration, the surface brought into play and with the rapidity of displacement before the membrane.

At a certain temperature the membrane of the plant becomes flabby, swells and in the end is simply a gelatinous mass that will partly dissolve in the juice. The softening of the membranes has serious consequences in the working of the diffusion battery, which will be discussed under another caption. This softening takes place at about 83° C. When beet cossettes are mixed with a certain volume of water and stand for a reasonable interval of time there will follow a perfect equilibrium, as before pointed out, and the exterior water will mix with the juice in the beet cells. In a

diffusion battery water passes through a series of receptacles known as diffusors, in which it comes in contact with the beet slices. The success of the operation largely depends upon the road travelled; if it is too limited, the cossettes will not be exhausted of their sugar through the diffusion action, but if the period of contact is increased the length of the circuit may be decreased. Evidently by using a large volume of water and increasing the temperature the operation would be accomplished more rapidly. From what has been said it is apparent that the operation depends upon many factors which have a mutual action upon one another, and it is for the technical man to determine under what circumstances the most satisfactory results may be obtained by diffusion and the maximum sugar extracted. Allowance must be made for the different changes which can supplement or replace each other. Among the interesting considerations relating to the phenomena occurring during diffusion are those mentioned by SCHWARZER,* and from his work many important theoretical facts may be quoted. When a complete equilibrium exists between liquids in the presence of one another (water and cellulary juice) it is mathematically possible to determine what will take place.†

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* Oe.-U. Z., 1, 561 and 659, 1872.

† As an example of these calculations, which are too long to give in full mention may be made of the following:

Let $Z$ = the weight of the juice, that is about 96 per cent of the total weight, of the beets contained in the diffusor;

$p$ = the quantity of crystalloid per cent of juice;

$P$ = the weight of the liquid saturating the cossettes in the diffusor;

$M$ = the percentage of crystalloid contained in per cent of liquid saturating the cossettes;

$$\alpha = \frac{Z}{P}; \quad \text{consequently } Z = \alpha P.$$

The absolute weight of the crystalloid $= \dfrac{Zp+PM}{100}$.

If $Q$ is the per cent of the mixture one would have

$$Z+P : \frac{Zp+PM}{100} = 100 : Q.$$

$$Q = \frac{Zp+PM}{P+Z} \text{ by substituting } Z \text{ for } \alpha P.$$

$Q = \dfrac{M+\alpha p}{1+\alpha}$ is the equation used as a basis for the calculations by means of which one can ascertain the concentration in each diffusor. If we suppose

When a diffusion battery is in full activity the juice of the last diffusor of the series is drawn off, and the diffusion juice that follows is sent to the diffusor recently filled, which becomes the last. The compartment which is first filled receives a volume of water equal to that of the juice drawn off and then a volume equal to that sent upon the first cossettes, after which it is isolated from the battery, and the diffusor that follows is treated in the same manner. This manipulation is repeated indefinitely. The volume of juice drawn off being constant and the water that takes its place being the same, the concentration of the juice at a certain period will be the same for each diffusor and the residuum cossettes will be uniformly exhausted. This working has been reduced to a complicated mathematical formula whose various solutions agree with practical experience only a part. The theory that the exhaustion of the sugar from the cossettes in the battery is in direct ratio to the number of diffusors and the volume of juice drawn off for a given weight of beets is correct, but when these facts are elaborated in figures strange results follow. It is asserted, for example, that the sugar percentage of the exhausted cossettes from a nine-diffusor battery can never fall lower than one-tenth of the sugar they originally contained when 100 per cent of juice is drawn off. MALANDER says that diffusion is not an intermittent operation, and that this phenomenon of diffusion, or the seeking of an equilibrium between the juice in the beet cell and the exterior liquid is not repeated nine times in a nine-diffusor battery but an indefinite number of times. These phenomena are far too complex for expression by any existing theoretical formula, and, therefore, the deductions are greatly misleading.

**Slice carriers.**—The cossettes fall directly from the slicer into the diffusors when the battery is circular, the distributing hopper being simply moved from the top of one compartment to another. One objectionable feature of this arrangement is that it demands an exceptionally high building as the beet slicer must be placed at an elevation that will allow sufficient slant for the rotating distributing hopper. At Prague efforts were made to overcome this difficulty

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the very simple case where $\alpha = 1$ and $p = 16$, the concentration in the diffusors would be as follows:

| First Diffusor. | Second Diffusor. | Third Diffusor. | Fourth Diffusor. |
|---|---|---|---|
| 8 | 12 | 14 | 15 |

This shows that the concentration of the liquid rises rapidly, and this is practically shown to be the case.

by having the entire battery rotate around a central pivot, while all the diffusors passed successively in front of a fixed distributing hopper. This arrangement was abandoned in Bohemia* when large diffusors were introduced, but in France it was much in vogue. This complicated appliance will be described later.

The straight-line battery cannot be so readily filled. Its diffusors are supplied with cossettes by a horizontal carrier, and when the slicer is too low to feed this carrier directly the cossettes are raised to the desired elevation by the use of a spiral or an endless chain with pockets. The spirals are objectionable in that there is more or less crushing of the beet slices. In order to obviate friction between the spiral and the trough a certain space must be allowed in which small particles of beet become lodged, and these soon ferment, creating a source of infection for the fresh slices with which they come in contact. The endless band or chain and bucket (or pocket) systems also have their weak points. The clogging difficulty in spirals may be overcome by constructing the spiral of iron bands.

The horizontal carriers most used belong either to the rake or band systems, both of which give satisfaction. The *rake carrier* is shown in Fig. 88. If the beet slices are raised from below by the slanting spiral *A* they fall into a horizontal trough. The rakes, which are all on an Ewart chain and revolve on the cog-wheels *B*, push the cossettes forward until they reach the distributng hopper *C*, and fall into the diffusors placed on the floor beneath. This rake carrier needs very little attention and the chains may be readily renewed or repaired. It is important that the chain be only reasonably stretched, otherwise the friction would be too great. A series of openings is provided for in the carrier which may be closed or not as circumstances require. The distributing hopper may revolve so as to feed the diffusors on either side of the carrier, and each one communicates with four compartments. The number of hoppers consequently is regulated by the size of the battery, for instance, for a 16-diffusor double-line battery four hoppers would be needed. Particles of beet always become attached to the teeth of the carrier and are thrown on the ground when the rake band reaches the end of its journey. These particles are collected in a basket and at certain intervals may be emptied directly into the diffusors by hand. The horizontal carrier, even of the rake

* N. Z., 2, 19, 1879.

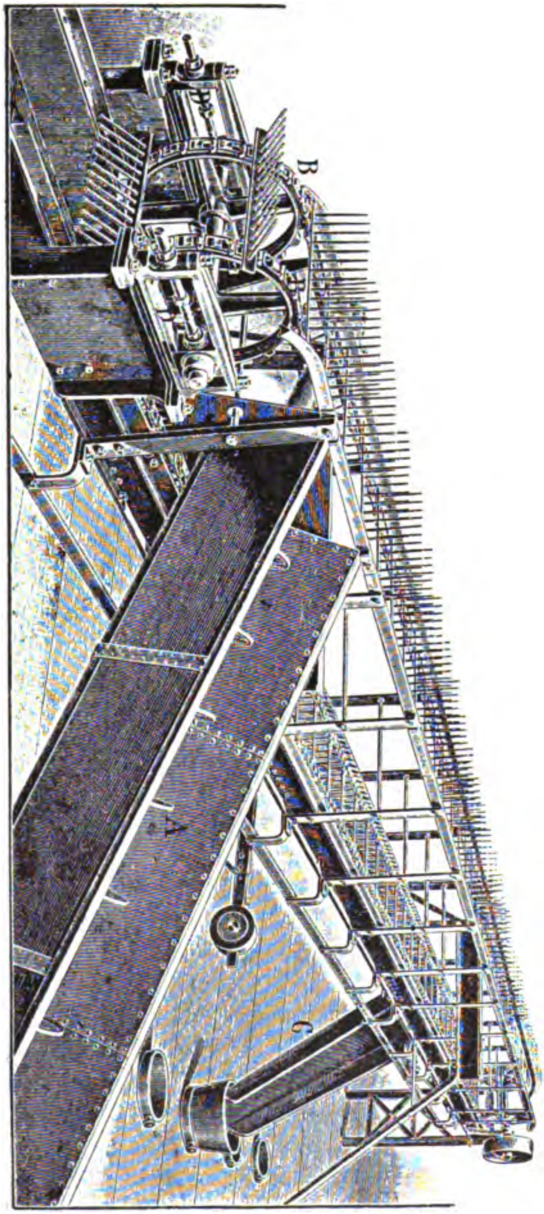



Fig. 88.—Rake Carrier with Feeding Hopper.

model, is adaptable to many special circumstances, and in Fig. 89 its arrangement when the beet slicer is on the same floor as the top of the diffusors is shown. This plan does away with the necessity of elevating the slicer whose vibrations then demand a firm and expensive support. The endless band carrier of the PAULY type (Fig. 90) consists of a long and moderately wide rubber belt, *g*, placed in a horizontal position. The cossettes are collected by curved scrapers, *c*, *d*, which communicate with the movable, distributing hoppers placed beneath, and are moved by trolleys on the upper and lower rails, *ss'*. This arrangement permits all the diffusors to be filled with beet slices in turn. The rubber belts are generally 50 cm. wide and move at a velocity of 2 to 5 meters per second, depending upon the requirements of the case. They revolve

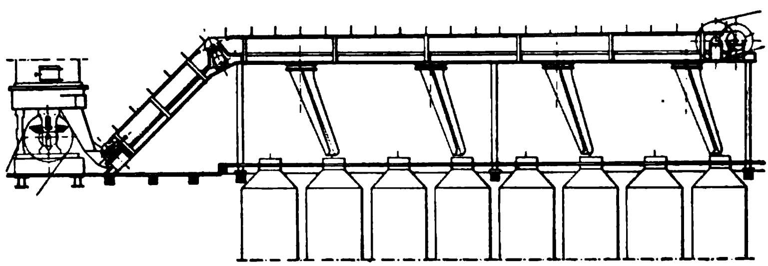


FIG. 89.—Arrangement of Carrier when Top of the Diffusors and Beet Slicer are on the Same Level.

on two end drums, one of which is movable. The tension of the belt should be moderate, otherwise it will adhere to the drum. The band moves on rollers that are placed at intervals for holding the upper portion of the belt, upon which the cossettes are circulating, rather than for the bottom part, where only the weight of the band proper is to be supported. On top the rollers are placed in pairs in front of each diffusor so as to enable the band to better withstand the pressure of the sheet-iron scrapers *c*, *d*. The portion of the slice distributor that comes in contact with the belting is of wood and is arranged so that it may be adjusted in allowing for wear. In some cases movable brushes are used instead of wood.

Experience seems to show that it is very advantageous to give the curve *cd* of the scrapers a parabolic shape rather than an angular one, in order that the resistance offered to the cossettes may be less when the direction of the motion is changed. In regard to the brushes it is to be noted that when they are in the least worn the cossettes are carried under by the moving band. One

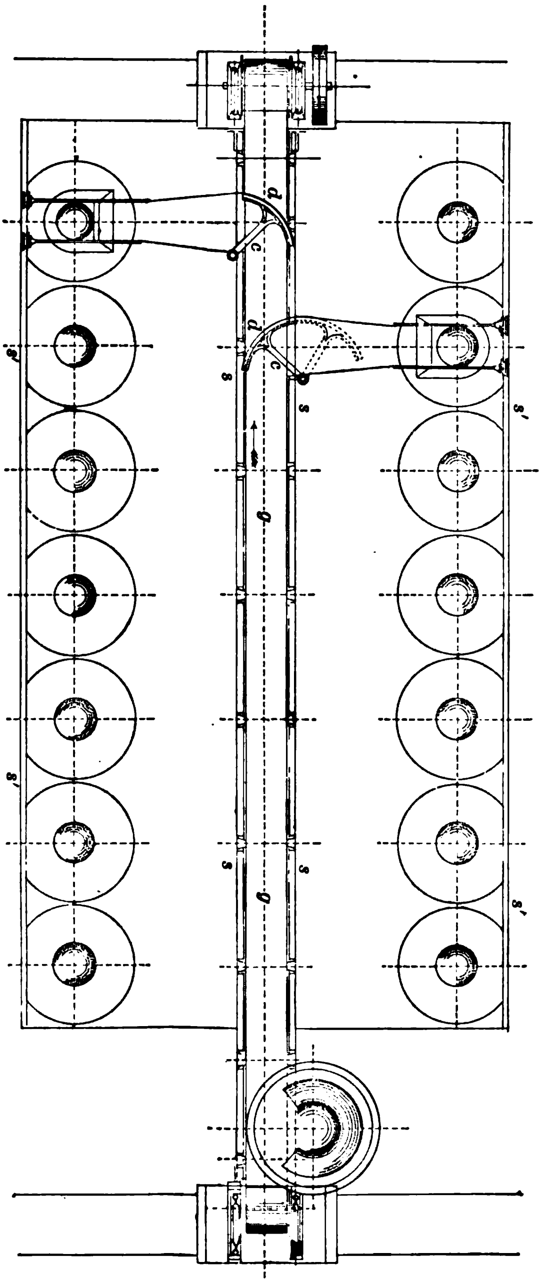



Fig. 90.—Plan of Pauly Band Carrier with Distributing Hoppers.

of the essentials for the satisfactory working of this band is that its ends be properly cemented so that the belt, taken as a whole, is perfectly straight. Excellent results are obtained by sprinkling water under the belt where it comes in contact with the drum, thus preventing adhesion between the two or between the belt and the small supporting rollers should the rubber become heated. A moderate spraying on top may also be desirable as it facilitates the sliding of the brushes. There are several modifications of these carriers, which, however, are of little interest.

In certain Austrian beet-sugar factories * the cossettes from the slicer fall into one-rail suspended cars having a capacity equaling that of a diffusor. They are placed in position and emptied at once. This plan works well because the opening on top of the diffusor is of an exceptionally large diameter. Experience shows that the cars should not be cylindrical but cubical. When the bottom is removed the beet slices all fall at the same time and distribute themselves in the diffusor. This arrangement tends to increase the working capacity of the battery, for the reason that the diffusor need not stand idle while the beet slicer is giving the necessary volume of cossettes. FOELSCHE † over twenty years ago proposed a very original mode for transporting the cossettes from the slicers to the diffusor. According to his scheme they were to be floated in an inclined culvert in which diffusion juices circulated. But the large volume of juice needed for this practice involved fermentation and consequent sugar inversion, and the plan was subsequently abandoned.† Experience shows that the rubber belt carrier should be placed about 1 meter above the top of the battery, which means that the piping, valves, etc., must be attached on the outside. On the other hand, in the case of rake carriers, they may be put between the two lines of diffusors The last made is that one which is best adapted to existing conditions.

**Diffusors.**—The receptacles in which the sugar is extracted from beet cossettes are known as diffusors. When considered collectively they form what is known as a battery, the number of compartments or receptacles varying from 6 to 16. The bottom of each one communicates with the top of the next in the series. Their shape should be such that no matter what is the position of the slices they will be thoroughly exhausted of their

* Z., **30**, 911, 1880. † N. Z., **13**, 14, 1887.

sugar without in any way retarding the circulation of the juice. The shapes of the tops and bottoms of the diffusors are very varied. The first types were cylindrical and had a manhole on top and a cover. For emptying laterally there was another manhole and a discharge valve or door (Fig. 91). The emptying of the diffusors offered considerable difficulty, and from the very beginning of the industry it was realized that some more practical mode must be adopted.

Without doubt the exhaustion of sugar from the beet slices differs in different parts of the diffusor. But while there is ample

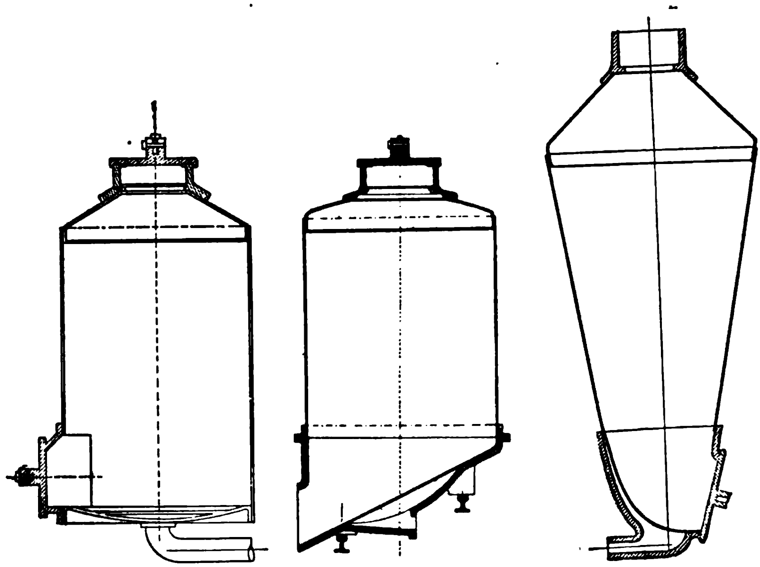


Fig. 91. Fig. 92. Fig. 93.

Fig. 91.—Cylindrical Diffusor.
Fig. 92.—Diffusor with Inclined Bottom.
Fig. 93.—Diffusor Larger on Top than on Bottom.

authority to show that this difficulty may in a measure be overcome by adopting some special modification in the shape of the receptacle, it cannot be admitted that it plays the important rôle frequently claimed. Conical diffusors have been constructed and used with more or less success.

At first efforts were made to facilitate the emptying of the diffusors by giving the bottom a certain inclination towards the lateral discharge opening (Fig. 92), then they were made very wide at the top, becoming smaller at the bottom, with an inclined manhole or

emptying door (Fig. 93). To prevent excessive settling or jamming efforts were made to construct inclined diffusors, but all these shapes were one after another abandoned, either on account of the mechanical difficulty of their practical working or because the sugar exhaustion of the cossettes was not as complete as was expected. Evidently the direction of the circulating juice depends upon the shape of the diffusor, and in most of the existing forms there were zones in which the juice circulated only moderately, and consequently the desired effect was not produced. The most rational shape was the cylindrical one, as it represented the natu-

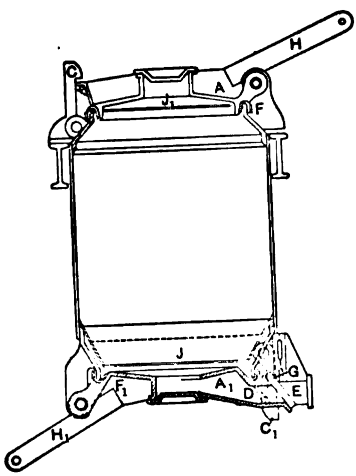



Fig. 94.—Cylindrical Diffusor.

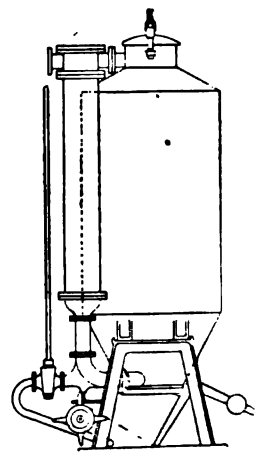
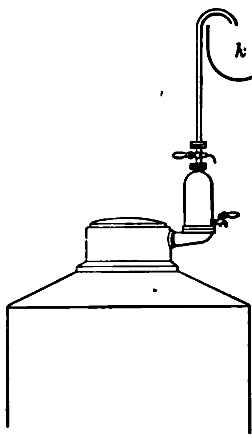


Fig. 95.—Large, Cylindrical Diffusors with Conical Bottom.

ral fall of the slices, provided, however, that the arrival and departure of the juice were conducted on a reasonable basis. It is this cylindrical shape that the Austrians have adopted for their standard diffusors, but it presents certain difficulties in the construction of the bottom emptying door, especially as shown in Fig. 94, when the diffusors reach abnormal dimensions. The movement is given through the levers $H$ and $H_1$; rubber joints are shown in $F$ and $F_1$, $J_1$ and $J$ being the perforated iron top and bottom. If the diffusors attain exceptional sizes, such as the Brunswick type, the main body remains cylindrical, but the bottom is slightly conical, which permits the use of an emptying door of slightly smaller diameter (Fig. 95). The upper truncated cone of a diffusor is of only relative importance. It may be mentioned, however,

that when the inclination of its sides becomes nearly horizontal the juice only circulates properly at the centre of the diffusor. This truncated upper cone has a neck supporting the cover and a suitable piping for the entrance of the juice. Upon the cover is a valve or cock for the exit of the air of the diffusor.

**Automatic valves** with inner floating disks are said to offer many advantages. By them the air contained in the diffusor can escape during filling. No cock is necessary, and the combination is such that exterior projection of surface frothing is impossible —a difficulty which has hitherto been most troublesome to over-




**Position on Diffusor.**
Fig. 96.


**Detail.**
Fig. 97.

Leyser Apparatus.

come. During the working of a diffusion battery the gases formed are, in a large measure, responsible for a poor juice circulation between the cossettes throughout the diffusors, but by allowing these gases to escape automatically the juice has a freer circulation through the beet slices. The valve through which the gases escape works during a period corresponding to the excess of pressure between the interior and exterior of the battery, that is to say, when the atmospheric pressure is less than that of the gases generated in the diffusors.

The Leyser * appliance (Figs. 96 and 97) is an excellent one, working on the same principle as the above-mentioned. It consists of a cylinder, *f*, in which moves a floating device, *g*, having

* N. Z., 5, 254, 1880.

a small valve, *b*, on top. When the liquid rises sufficiently it closes the pipe through which the gases make their escape. The frothing may be collected at *k*. Two small cocks, *h* and *i*, permit samples of the liquid and gas to be taken. The apparatus is bolted upon the neck of the diffusor. The LABBÉ * (Fig. 98) automatic purging device is fastened to the cover of the diffusor. It consists of two compartments, *A* and *B*, which communicate through a pipe, *E*. This has two holes, *F*, corresponding to the upper part of the chamber, *A*. A float, *D*, covers these holes when the juice rises sufficiently to lift it. The apparatus includes a safety valve, *S*, which becomes active when the pressure is abnormal and the floating device stops working.

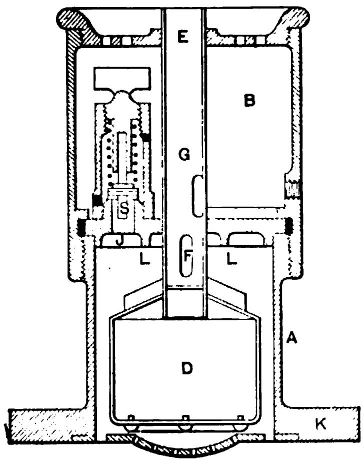


FIG. 98.—LABBÉ Automatic Purger.

The cover of the diffusor generally rotates on a pivot, though in some cases it works on hinges and has counterpoid attachments. This mode gives much satisfaction when the size of the diffusor becomes abnormal, and is adopted in all cases when a hydraulic joint is used.

**The shape of the bottom part** of the diffusor depends upon the mode of emptying. When the operation is to be effected by a lateral door the lower portion of the diffusor is cylindrical, while the perforated bottom is horizontal and has the same diameter as the diffusor. In some cases, however, the rounded bottom is opposite the lateral manhole, which arrangement facilitates the emptying of the exhausted cossettes. When the emptying is done from the bottom it also is cylindrical, provided the bottom-emptying valve has the same diameter as the diffusor, which is generally the case. When the lower part of the diffusor is conical its sides incline at an angle of about 45°. The opening for filling frequently has the same diameter as the bottom. As experience shows, the upper closing should be about half the diameter of a diffusor of

* S. I., **52**, 594, 1898.

an average capacity (40 to 50 hectoliters). For larger diffusors the size of the opening may be somewhat reduced. There can be no objection to having the upper opening somewhat smaller, but at the bottom these proportions had better be maintained.

**Doors.**—Diffusors emptying laterally have swinging doors and are closed by suitable tightening bolts. Their size must be very limited, and Roehrig and Koenig have attempted to overcome this difficulty by constructing double folding doors. The door for bottom emptying always works on pivots or hinges and has counterweights at the end of suitable levers; it is held in position by a screwing device. When a door of this kind is suddenly opened it is projected against the diffusor, notwithstanding the action of the counterpoids. This may in a measure be prevented by slightly displacing the counterweights, but by so doing the doors get out of shape, and this causes numerous other complications, such as clogging of cossettes in the joints, etc. Faber (Fig. 99) very cleverly overcomes the difficulty by placing a curved spring at the end of the road travelled, and underneath it another spring which exerts sufficient pressure to keep the door in a fixed position during the entire emptying. Numerous other appliances have been invented with the same object in view. In the Passchen * combination an eccentric is attached upon a special axis, and works upon the heel of a brake bolted to a long iron bar, the end of which has a slight play in an eyelet attached to the stone foundation of the diffusion battery or to the diffusor proper. Owing to the eccentricity of the disk attached to the axis of the valve, the friction of the brake increases with its motion, and in order that the brake's action may be comparatively slow the bearing of the axis has a rod which presses the heel against the eccentric. The iron bar upon which the heel is attached constitutes the long arm of a lever which deadens the violence of the shock so as to obviate any possible harm to the masonry or to the diffusor.

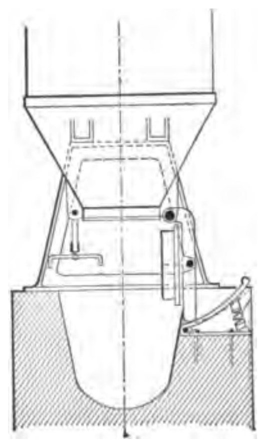


Fig. 99. — Faber Automatic Emptying-door Arrestor.

* Z., 50, 1132, 1900.

The ERMES * idea is also interesting. Two horizontal plates are used which open just as do the blades of scissors, and when not working they are held together by a spring. When the diffusor is to be emptied the blades are separated by a bar of iron, which advances until it comes in contact with an elastic bumper that softens the shock, and in this position it is held in a groove by the springs

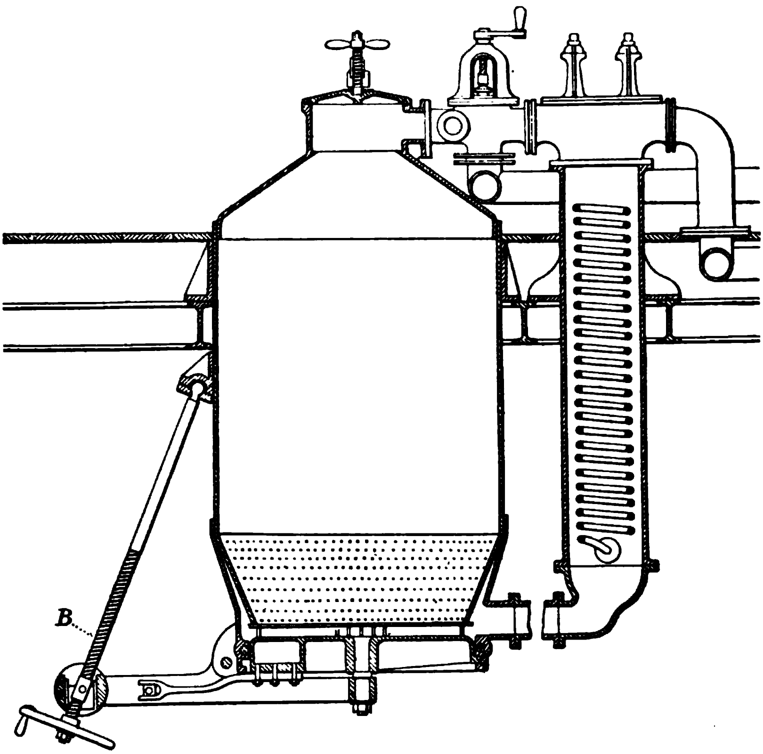



FIG. 100.—CAIL Closing-door Combination.

of the blades. By a special lever combination worked from the top of a battery the diffusor may be closed by its rotating bottom. A special signal appliance on the vertical stem connecting with the waste water of the diffusors acts as an alarm during the entire period that the valve remains open, whereby many mistakes in working the belting can be obviated.

When the bottom doors are of exceptional size rather complicated appliances must be used for their working. The closing door

* D. Z. I., 24, 1866, 1899.

of the Cail model (Fig. 100) is held by one end of a lever revolving around one of the exterior sides of the diffusor. The other arm of the lever has a nut that works along the screw-thread bar *B*. By simply turning this nut from the bottom the door of the diffusor readily opens.

A more recent type of a large diffusor of 50 h.l. capacity, made by the same company, has a maximum height of 2.5 m. of beet slices in its interior, which is said to allow a satisfactory circulation of the juices. The calorizator is tubular and has a heating surface

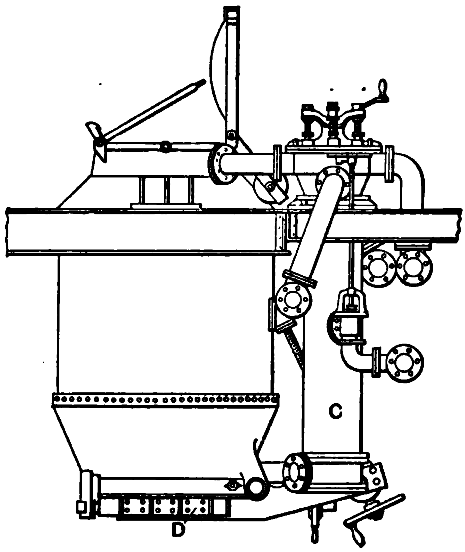



Fig. 101.—St. Quentin Diffusor with Large Emptying Door.

sufficient to give excellent results with the vapors taken from the evaporating apparatus (triple, quadruple, etc., effects). The doors for closing and emptying allow the juice to enter in the centre, one of the essential conditions for regularly exhausting the cossettes, and are worked from the upper floor. Corresponding to the top of the diffusors are hydraulic joint attachments, which are arranged in such a manner that in case of rupture the hot juice is projected upwards and the workmen in charge are not scalded—an accident of common occurrence.

The St. Quentin arrangement (Fig. 101) is also well understood. The large diameter diffusor of the St. Quentin Co. has a very large closing and emptying door, *D*. The type is shown in the

cut herewith, Fig. 101. It has a capacity of 50 h.l., and a special system of perforations of its closing and emptying valves forces a methodical circulation of the juices through the cossettes. There is a tubular calorizator, *C*, attachment, with a large heating surface, the appartus being heated with vapors from the quadruple effect. There are four valves for water, juice, etc. The arrangement is entirely new and permits of filling at a high temperature. The juice may be drawn off in the same direction in which the diffusor is filled.

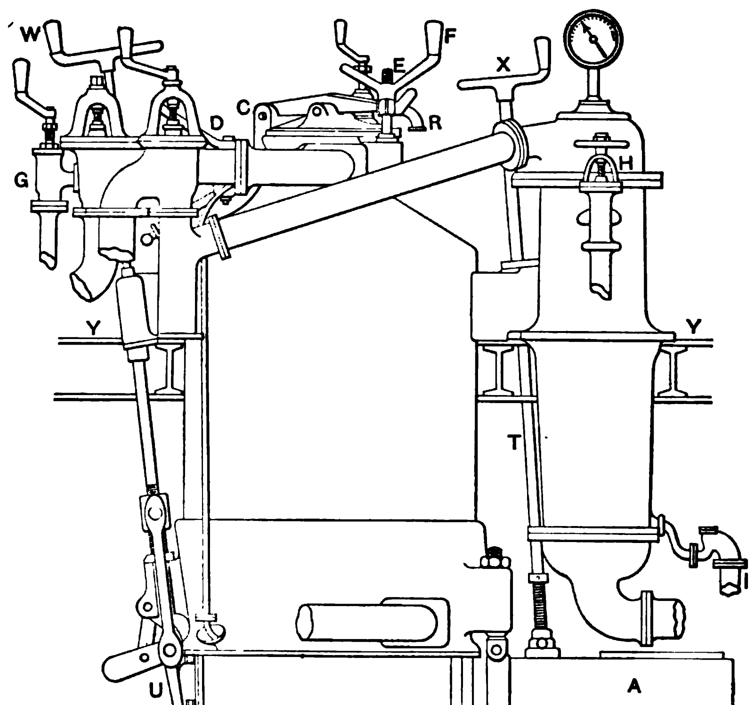



FIG. 102.—FIVES LILLE Arrangement for Opening Large Bottom Valve from Above.

It is frequently desirable to effect an opening from the top of the diffusor. With this idea in view the FIVES LILLE Co. (Fig. 102) placed the handle *X* above the diffusion floor *Y*. The closing door of this diffusor is well balanced by a counterpoid *A*. However, as the doors have an exceptional diameter, and as the joint is not tight, notwithstanding the hydraulic attachment, it is still further hooked up by two clicks, below which are the eyelets *U*, which

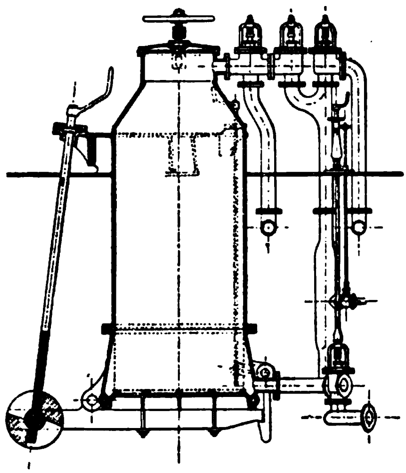


FIG. 103.—MARIOLLE PINGUET Diffusor with Bottom Emptying from Top of Diffusor.

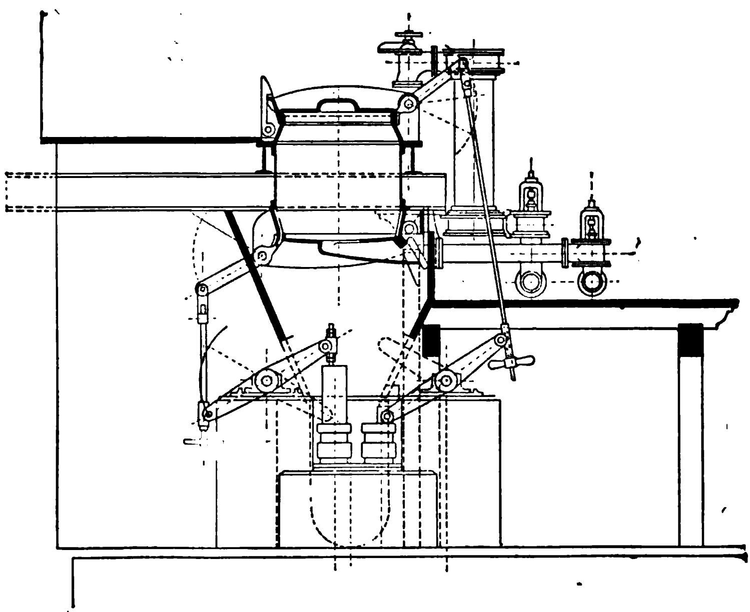


FIG. 104.—MAERKY and BROMOVSKY Hydraulic and Automatic Bottom Closing Device.

may be tightened from the top by turning W. The two clicks are simultaneously worked.

The Mariolle Pinguet diffusor (Fig. 103) has about the same arrangement, but is of a much simpler construction. Do what one may, the working of these large doors always offers considerable difficulty, and the manœuvering takes much time. The screw thread on the connecting bar for their working is very fine and always necessitates many revolutions of the handle before much headway is made toward fully opening the door. This fact has led to bottom emptying by automatic combination, but these have had very few practical applications *. A very strong cylinder is connected with the door of the diffusor by a well arranged system of levers. By introducing water into this cylinder the pressure causes the piston in the interior to change its position and the door opens. By a judicious regulation of the water the closing may be regulated very methodically, being rapid at first then less so, and finally very slow, so as to attain the desired pressure for a tight joint. The diffusor of Maerky and Bromovsky (Fig. 104) is one of this kind, and while having certain advantages is too complicated for general use.

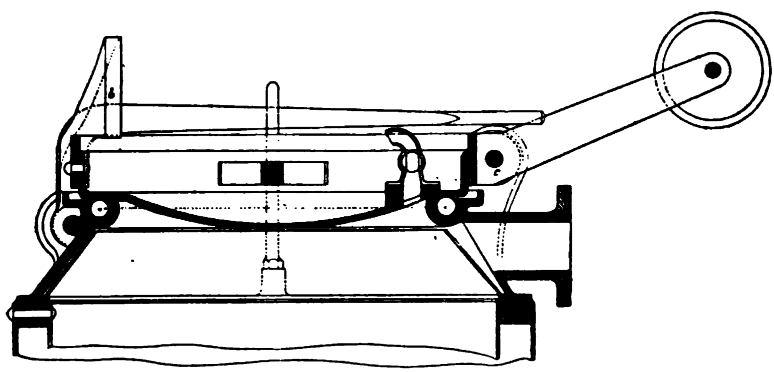


Fig. 105.—Deuzenberg Arrangement for Closing Top of Diffusors.

Doors of excessively large diameter were never practically worked until the Deuzenberg † combination was invented. The closing of the top door is effected by the joint and explains itself upon an examination of Fig. 105. When these doors or covers are of excessive size it would be difficult to obtain the desired tightness

* Z., 30, 912, 1880. † Z., 29, 869, 1879.

by the simple pressure of a screw upon an inserted rubber ring. For this solid ring is substituted a hollow one in which water is forced to circulate through pressure. The rings have a diameter of about 50 mm., and the pressure needed to bring about the desired tightness is about 1.5 atmospheres in excess of that existing in the diffusor, or about 3 atmospheres. This hydraulic pressure is given to all the joints of the battery by a small hydraulic pump with a pressure accumulator. The latter consists of a large piston of 250 mm. diameter sliding in a compartment filled with water and loaded with weights until the desired pressure is obtained by introducing water with a force pump.

**Screens.**—The beet slices in a diffusor do not rest directly upon the lower bottom cone nor upon the emptying door, but are held up by a false bottom constructed of perforated sheet iron. The arrangement of this perforated disk and the position of the exit pipe have a great influence upon the rational flow of the liquid through the diffusor. When the emptying is to be done on the sides the sheet-iron strainer is always placed at the bottom of the apparatus and the exit pipe for the juices is exactly opposite to the centre of this disk. On the other hand, when the emptying is done from the bottom of the diffusor and the compartment has a conical bottom in the direction of the latter, there is also an inclined strainer; in other words, in such cases the perforated false bottom has the shape of a truncated cone (Fig. 100). This becomes indispensable when the diffusor is comparatively high, and consequently the bottom is relatively too small to permit the passage of the juice. However, even with these precautionary measures lateral currents will be created and the conditions shown by Quis * in the diagram (Fig. 106) occur. The cossettes in the central portion will not be as thoroughly exhausted of their sugar as those on the sides of the diffusor, for the reason that the juice follows the path of least resistance.

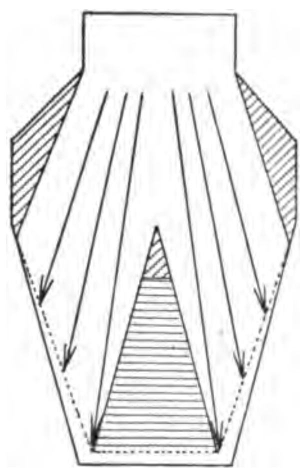


Fig. 106. — Quis Diagram, showing Circulation of Juice in Diffusor.

* Oe.-U. Z., 9, 124, 1880.

It is not sufficient that the free passages be several times larger than the section of the exit piping, for the cossettes could readily fill up these spaces, especially when the slices are soft, but the open spaces at the bottom should also be as great as possible. The typical perforated bottom would have the greatest number of holes or openings consistent with possessing the rigidity requisite to resist the pressure of the cossettes. The perforated bottom is attached to the closing valve by means of which the emptying is done. FOGELBERG * found it desirable to have the holes on the slanting portions of the perforated plate made smaller than those at the bottom or else kept further apart. When the bottom holes have a section of 1 sq. cm., there is always danger of the suspended pulp being carried forward with the juice, and special care should be taken to separate it. Many now prefer oblong holes in the false bottom instead of round or square ones, or even slits, and there is much to be said on both sides. But one fact is certain, the round openings are more readily kept clean. It has been proposed to use undulated perforated sheet iron † for this purpose. The advantage claimed is that a greater surface would thus be obtained through which the juice could circulate, but the idea has never been generally introduced. During the sugar campaign it is frequently found necessary to thoroughly clean these false bottoms, and it must always be done when the slicing season is at an end. In very large diffusors the pressure of the cossettes on one another is so great that they fill up the passages and the juice cannot circulate, or they stop up some of the holes and remain in position after the diffusor has been emptied.

It has been proposed to relieve the pressure of the cossettes on the perforated bottom by the use of suspended chains, transverse strips of wood, and gratings. A certain result is obtained by such expedients, but as the emptying of the cossettes from the diffusors becomes more difficult they are used only in special cases, as when working frozen or inferior beets. At present it is no longer customary to place a perforated plate on the upper neck of the diffusor as was formerly done. This was not only of little or no use but offered objectionable features; owing to the reduced dimensions the circulation was retarded as soon as the preceding diffusor sent over particles of cossettes in suspension in the juice. Then strainers are useless, because the juice circulates in the diffusor

* C., 6, 734, 1898. † N. Z., 12, 203, 1884.

from the top to the bottom, and consequently the beet slices have no tendency to escape from the diffusor in that direction. Under all conditions there is always certain loss of space in the diffusors. Among the means that have been proposed to prevent this may be mentioned those of DELTOUR * and MIOT, who introduce into the neck of the diffusor at a short distance from the side a circular perforated disk, which may be either fixed or movable, allowing a free circulation of the juice and an escape of air, but preventing the cossettes from entering the piping which forms part of the battery. The perforated disk should be as close as possible to the upper door and to the sides of the neck in order to prevent inactive spaces in the interior of this compartment, in which centres the juice has no dialyzing action. These dead centers have the effect of decreasing the concentration which is undesirable unless the battery is worked with the idea of obtaining very diluted juices. Whatever be the combination adopted precaution should be taken to allow sufficient space under the false bottom so that the circulating juice need have little or no resistance to overcome.

**Exit piping** for the juice is placed at the exact centre of the bottom of the diffusor if the exhausted residuum cossettes are to be removed through a lateral manhole. However, if the discharge is made through the bottom opening this central exit can exist only in exceptional cases. In the type of diffusor shown in Fig. 95 the exit is from the conical portion of the bottom. It is evident that there will be a tendency to produce at that portion juice currents very like those shown in the QUIS diagram (Fig. 106). If certain precautionary measures are taken, however, such as placing fewer holes in the slanting portion of the false bottom the difficulty may in a measure be overcome. Experiments have been made of drawing the juice off from diffusors that empty from the bottom by introducing a central exit with branches (*D*, *E*, Fig. 94). This has always been followed by certain complications, the difficult issue being the joint between *D* and *E*.

**Proportions for diffusors.**—In considering the shape of a diffusor the relation between the height and the diameter must first be determined. In theory the exhaustion is the more complete when the diffusors have a reasonable height with a comparatively small diameter. But as the height increases the stratum

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* Z., 52, 508, 1902.

of beet slices through which the juice must penetrate also increases and an increased resistance must be overcome. It must also be remembered that with a smaller diameter the size of the perforated bottom upon which rests the column of cossettes diminishes, and necessarily the number of holes it contains is also less, and some of them being always partially covered with cossettes the circulation of the juice is necessarily retarded. Practical experiments have been made with a view to establishing some relation between the diameter and the height of a diffusor that would lead to the most rational results. Up to the present time none of these conclusions can be considered as applicable to all cases, for the reason that the obstacles which the circulating juice has to overcome do not depend alone upon the distance travelled in each diffusor, but also upon the number of diffusors that are actually working in the battery, the free passage in the perforated bottom of the diffusor, the shape and nature of the cossettes, and the manner in which they distribute themselves during the process of diffusion.

As even with the same beets the composition of the juice varies in each factory, and may vary much more in different plants, it becomes evident that every variation in the mode of working tends to make the ultimate results very different. However, certain general rules for the principal dimensions of the diffusors may be laid down. If excessively fine cossettes are to be used low diffusors of large diameter should be used. For an average condition of working with cylindrical compartments as now used, a proportion between the diameter and the height of $1:1\frac{1}{4}$ to $1:1\frac{1}{2}$ appears to be satisfactory. The proportion 1:2 is exceptional, as it is thought more desirable to increase the number of diffusors in the battery in the proportion of $1:1\frac{1}{2}$. If very large cossettes are to be handled it is generally found better to use a diffusor of a comparatively small diameter and considerable height. The conditions just mentioned refer to ordinary diffusors. An important factor in this discussion is the velocity of the circulating juice. The more rapidly the juice flows the less time it will have to dissolve the sugar contained in the beet cells. The velocity of the juice depends directly upon the relation existing between the diameter of a diffusor and its volume, and SZYFER * obtained the best results when the juice circulated at a velocity of 18 cm. per minute

* D. Z. I., 18, 1529, 1893.

and the poorest results with a circulation of 40 cm. and more per minute. From data collected by Bouchon * it appears that the large diameter diffusors give the most satisfactory results when all conditions have been considered. By a series of arguments this authority arrives at the following formula:

$$\frac{T}{NCE}=V,$$

in which the $V$=proportionate value of the battery; $N$=number of diffusors; $C$=volume in hectoliters; $T$=average work per diem; $E$=average exhaustion (per cent sugar in the residuum cossettes). This formula has been applied in several cases with the following results:

Relation between Size of Diffusor and the Amount of Juice Extracted.

| Factory. | Proportion between Diameter and Length. | $N \times C$. | $T$. | $E$. | $V$. |
|---|---|---|---|---|---|
| A | 0.79 | 14×19 | 300 | 0.28 | 4.00 |
| B | 0.92 | 14×33 | 380 | 0.25 | 3.28 |
| C | 1.13 | 14×25 | 320 | 0.32 | 2.85 |
| D | 1.30 | 16×30 | 350 | 0.30 | 2.43 |
| E | 1.78 | 12×38 | 300 | 0.28 | 2.35 |

In each of these factories the amount of juice drawn from the diffusors was about the same. The advantage of large diameters is evident. Among the various European types the Brunswick ratio of height to diameter is high, while in those of the Maerky model it is low. The diameter of the diffusors may be readily calculated if the height and the total weight of beets to be sliced per diem are known; though no fixed rule can be given regarding the relation between diameter and height. For a certain method of working and a given quality of beets it should depend upon the number of diffusors in the battery and the volume of each diffusor. All batteries, for example, consisting of 14 diffusors, destined to work under same conditions, should offer a diffusion column of the same height whatever be the weight of beets being handled per diem. The diffusors should consequently all have the same height. A practical battery of 14 diffusors working 400 tons of beets

* B. As., **11**, 32, 1893.

per diem has diffusors of 1.30 meters in diameter and 2.5 meters in height; the relation, therefore, is $\frac{H}{D}=1.92$. At another factory handling 500 tons it was $\frac{H}{D}=1.72$, etc.

This whole question of the proportions of diffusors was thoroughly examined about ten years ago by SZYFER, who concluded that the volume of juice to be drawn off per 100 kilos of beets varies with the shape of the diffusor; that cylindrical diffusors in which $\frac{H}{D}=1.5$ gives the best result; that the shape of the upper cone forming the top has an important influence upon the exhaustion; that the most favorable angle is about 60°, and that the highest efficiency is obtained with juices circulating at a velocity of 18 cm. per minute. The total height of the diffusor gives the length of the juice column. In the case of active circulation this is 32.6 meters, supposing the battery to consist of 16 diffusors 2.25 meters in height, of which 14.5 are active. SZYFER maintains that the most essential considerations are the volume of juice brought in contact with each kilo of cossettes and the velocity with which it passes. The following formula gives considerable information:

$L=\frac{Sdh}{\frac{\pi r^2h}{2}}=2\frac{Sdh}{\pi r^2h}$ = volume of juice, in liters passing through 1 kilo of cossettes.

$S$ = volume of juice passing through diffusor;
$d$ = number of diffusors;
$r$ = radius;
$h$ = height.

The velocity of the juice per minute can be found by the formula

$$V=\frac{2S}{M\pi r_2},$$

in which $\frac{S}{M}$ = number of liters per minute and $M$ = number of liters necessary for the flow of $S$. If one supposes that $Q$ is the proportion existing between $L$ and $V$, then $Q=\frac{L}{V}=Md$. It may be concluded that the efficiency of a battery is proportional to the time the juice must circulate and to the total height of the battery. The time of circulation depends upon the diameter of the diffusors and the height

of the battery upon the height of each diffusor and their number. It is concluded that the best work is obtained with many diffusors of large diameters. Theoretically the normal number should be 12 per battery, and the capacity and size of each may be calculated, though these data are always somewhat empirical.

**Capacity.**—The diffusors differ greatly in capacity, varying from 20 to 100 hectoliters, although of late preference appears to be given to 50 or 80 hectoliters. Because of certain requirements of the fiscal laws very small diffusors, such as once were used in Austria, have now been abandoned as impracticable. On the other hand, with very large diffusors difficulties constantly arise, especially if the total production of the factory does not correspond to the dimensions or the cossettes are either too fine or not satisfactory. But while small diffusors may be operated more rapidly than large ones, as the column of cossettes offers less resistance to the passage of the circulating juice, yet they demand a larger volume of water in order to obtain the same degree of exhaustion of sugar from the beet cells. It was only with exceptionally small diffusors that the Austrians were able, under the now obsolete fiscal law, to run 1000 diffusors in 24 hours.

**The reheating of juices in the diffusion battery.**—As diffusion is best accomplished with a hot liquid, efforts have been made from the first to determine the mode of reheating that would lead to the best results. The methods, however, were faulty from the start. Formerly, before passing from one diffusor to another the juice was run into reheaters, and from there returned to the battery, but this mode was abandoned when the JASINSKHI * calorizators were invented. The calorizator which has undergone many improvements consists of a heating surface over which the juice passes on its way from the bottom of one diffusor to the top of the next. At Seelowitz, Austria, attempts were made (without, however, meeting with any great success) to reheat the juice in the interior of the battery by injecting live steam into the pipe connecting the diffusors.† These two modes—the use of a calorizator, and live-steam injection—are to-day being discussed by the advocates of both systems. The SIEGL and URBANEK method of heating the diffusors externally by the use of steam never found much favor. Upon general principles the calorizators are preferred, for with them the heating may be done with steam at low pressure obtained from the evaporating appliance, such as

* Oe.-U. Z., 6, 720, 1877. † Oe.-U. Z., 4, 363, 1875.

a triple or multiple effect, and under such circumstances it is very economical. For reheating with live steam one must use that taken from the boilers, which has disadvantages from a monetary point of view, and, furthermore, the juices drawn off from the battery would necessarily be much more dilute than those heated by the regular tubular calorizators. CLAASSEN says that practical experiments have yet to demonstrate that the dilution actually exists. There can be no doubt, however, but what all the injected steam condenses in the pipe of communication, and the juice is thereby diluted; but as the last extraction from the cossettes is accomplished in the diffusor recently filled, after which the juice is no longer heated in the battery, the dilution of that drawn off is hardly perceptible. It must not be overlooked that the use of the tubular reheaters is objectionable as regards the concentration of the juice in the diffusor which depends upon the proportion of cossettes to the capacity of this vessel. The greater the amount of beet slices in a diffusor the less space there will be for the circulation of juice alone and the more perfectly will the operation of diffusion be accomplished. The open spaces correspond to dead centres to which may be added the capacity of the tubular reheater. These reheaters also have the disadvantage of allowing sugar losses through leakage, which difficulty, however, is to be overcome by the use of live steam.

**Calorizators.**—The calorizator consists of a long steam chamber terminated top and bottom by plates holding the tin-lined brass tubes through which the juice circulates. Preference is given to this metal for the reason that it is the one least attacked by diffusion juices. The tubes are frequently slightly curved so as to allow for expansion under the influence of the high temperatures. In the SCHNEIDER and HELMECKE (Fig. 107) calorizator the lower tubular plate *J* is not firmly fixed to the main body of the apparatus, but is bolted upon a nozzle that passes to the exterior of the calorizator through a large stuffing box *G*, which connects the tubular cluster with the preceding diffusor. This arrangement permits the tubes to expand at will without the least possibility of a leak. *A* represents the entrance pipe for the juice; *B* the piping connecting with the following diffusor; *C* the pipe through which the juice may be drawn off; *E* the entrance for the steam. The heating chamber has at its upper portion a small tube *F* for the exit of air and non-condensed gases introduced with the steam. If low-pressure steam is used for heating purposes this

tube is put in communication with the condensor, otherwise it simply has an opening into the ambient atmosphere through a suitable small cock. Notwithstanding its diminutive size it is important that it be under close surveillance.

At the bottom of the heating chamber there is a tube *H* for the exit of the condensed water from the steam that has yielded a certain number of calories to the juice in the tubes during its passage. To this tubular attachment a small valve is adapted which opens as soon as the quantity of condensed water from the calorizator is sufficient to overcome its resistance. Instead of a valve a syphon tube may be used. When heating is done at very low pressure the tube has a purging cock connecting with a water pump. The small cock *I* permits a sample of the condensed water to be taken. There are tubes opening on either side of the tubular disk into two small chambers connected with the preceding diffusor. Generally the upper chamber has a thermometer attachment, though it is frequently placed on the pipe connecting the calorizator with the diffusor. In some types of calorizators the top of the apparatus works on hinges and may be opened for cleaning and repairing. In the calorizator shown in Fig. 107 the top may be taken off by turning over three bolts working on screws.

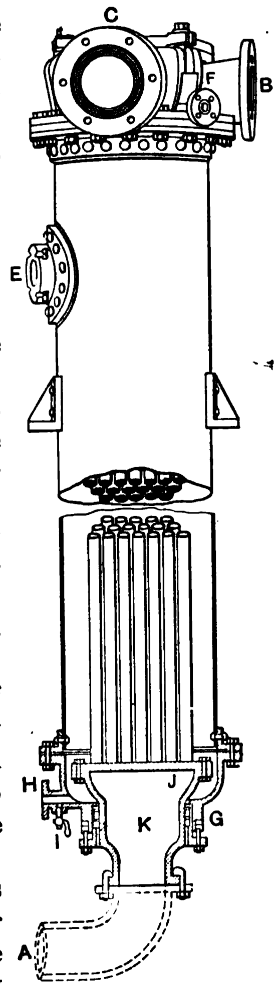

FIG. 107.—SCHNEIDER and HELMECKE Calorizator.

The tube *A* has a piping which permits the exit of the water from the diffusor when it is emptied. This pipe may have either a valve or cock attachment. By connecting the heating pipes of a calorizator in series it is possible to obtain an up and down circulation of the juice before it enters the next diffusor, which brings about a much better transmission of the heat. There is evidently a rational limit to this circulation which cannot be

exceeded without disturbing the pressure in the battery. The total heating surface of each calorizator depends upon the size of the diffusion battery with which it is connected, and is influenced also by the rapidity of working. As a general rule 0.1 square meter of heating surface may be allowed per hectoliter capacity of the diffusor. Experience shows that to keep the calorizators in a first-class condition the tubes should be thoroughly brushed every week, although for the rapid circulation types of apparatus this is not so important, because the deposits on the inside of the tubes are much less than when the juice circulates more slowly. The coil mode of heating (Fig. 100), having in view the same object as is realized by a calorizator, has now entirely gone out of use.

Too little attention is given to the capacity of calorizators. Evidently during the mashing in a diffusor the juice contained in the calorizator has less density than that of the diffusor with which it is connected, and when the circulation is resumed the contents of the calorizator are emptied into the next diffusor and are followed by the richer juice. It is desirable to do away with juice chambers, or at least to limit their size, and arrange as far as possible to have the juice circulate only in quantities proportionate to the piping.

**Injectors.**—From the time when calorizators were first used efforts have been made to substitute steam injectors which are much less expensive. When the mode was introduced the installation was very faulty, and when the steam came in contact with the juice it made a deafening sound. VIVIEN mentions a case where the steam was injected into the pipe connecting the diffusors through a copper tube which necessarily caused an intense buzzing owing to the condensation of the vapor in the juice. This difficulty may be overcome by the use of the BLANCKE and KOERTING injector (Fig. 108), which consists of six small truncated bronze cones, each having heels that keep them well separated. The distance between the cones is determined in advance, thus leaving in the centre a passage for the steam. The cones are held together by a hollow metal stopper well screwed down. The steam passes through this injector and carries with it through the open spaces a certain quantity of juice. The condensation is thus retarded and split up and all

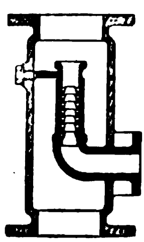

FIG. 108.—BLANCKE and KOERTING Injector.

noise suppressed. These injectors are placed in the pipe where it connects the bottom of one diffusor with the top of the following one. It was customary formerly to use copper or forged iron piping so that it would not suffer from excessive jolting, but of late cast iron has been employed owing to the use of the special injectors just mentioned.

## Diffusion Battery.

**Number of diffusors.** — There are numerous interdependent factors that go to make up satisfactory diffusion, and it is almost impossible to make allowance for all of them. As previously pointed out the shape of the diffusor, notwithstanding many assertions to the contrary, plays a very important rôle, while the completeness of the exhaustion desired, the rapidity at which the battery is worked, and the degree of concentration of the juice, are all to be considered. The shorter the diffusors and the more rapidly they work the greater will be the number of compartments the battery must have in order to obtain the desired limit of sugar extraction. When the main object in view is to obtain very concentrated juice the requisite number of diffusors must be available. The number depends largely upon the velocity of the circulating juice and the height of the columns of cossettes in the compartment. On this question opinions differ very much. Attention has already been called to the fact that Szyfer admitted a velocity of the juice in the battery of 18 cm. per minute, the total height of cossettes to be penetrated under these circumstances being 32.6 meters. If this height is divided by that of the diffusors the number of active compartments necessary to give the desired result is attained. It is customary to have one or two additional diffusors for the filling and emptying.

All facts considered, a battery of 16 diffusors appears to be the most desirable to meet these special conditions, although excellent results have been obtained with batteries of only 8 compartments, and many factories with batteries of 16 diffusors divide them, thus giving a double series of 8 each. Among those advocating this mode is Aulard.* At the end of a campaign when the beets are frozen excellent results may be obtained by the double series. This division of the battery brings about an

* B. As., **9**, 287, 1891.

increased efficiency, and although the juices under these conditions are not so concentrated the difference is very slight when the cossettes are made exceptionally thin, which they may be in this case as they have less resistance to overcome, the total pressure producing the juice circulation in the battery being less. Under another caption the divided battery is further discussed.

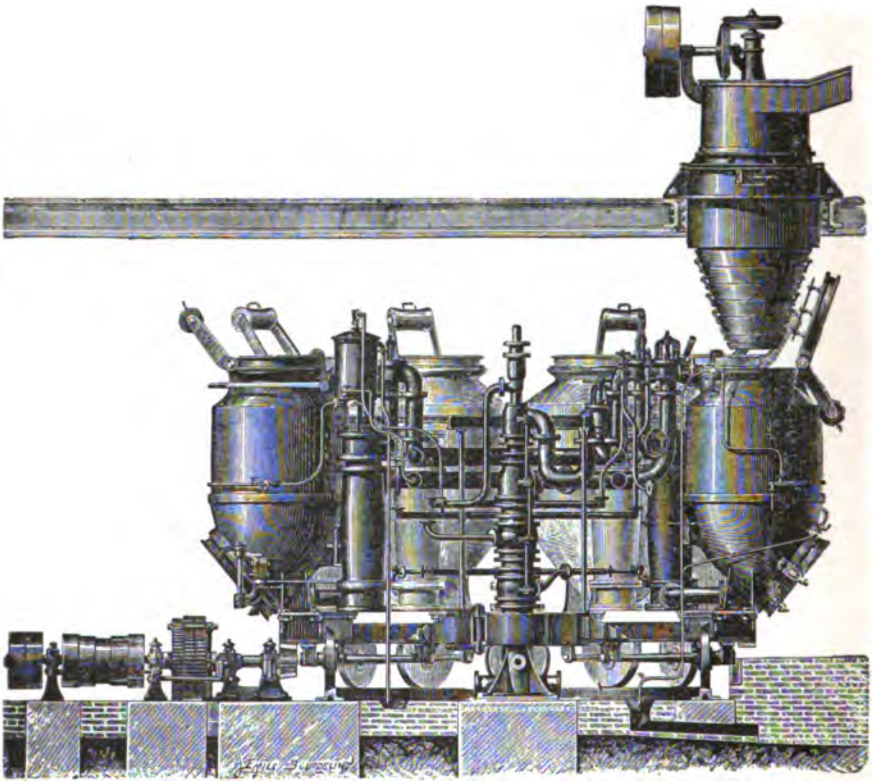

FIG. 109.—Elevation of Rotating Diffusion Battery.

**Arrangement.**—The diffusors are generally arranged in one of two ways—in a circle or in a straight line. In the old factories the former mode was very much in vogue.

**Circular diffusion battery.**—The most interesting type of circular diffusion batteries is the rotating apparatus constructed by LECOINTE and VILLETTE, an elevation and plan of which are shown in Figs. 109 and 110. The diffusors are arranged around a

circular cemented pit, the latter receiving the refuse cossettes. Between each diffusor is placed a calorizator. The roots are raised by an elevator and thrown into the slicer located at a certain elevation above the battery, and around this apparatus a suitable flooring is arranged. Movement is given to the slicer from above by suitable gearing and below it a slanting distributing apparatus is arranged, which may be connected with any or all of the diffusors.

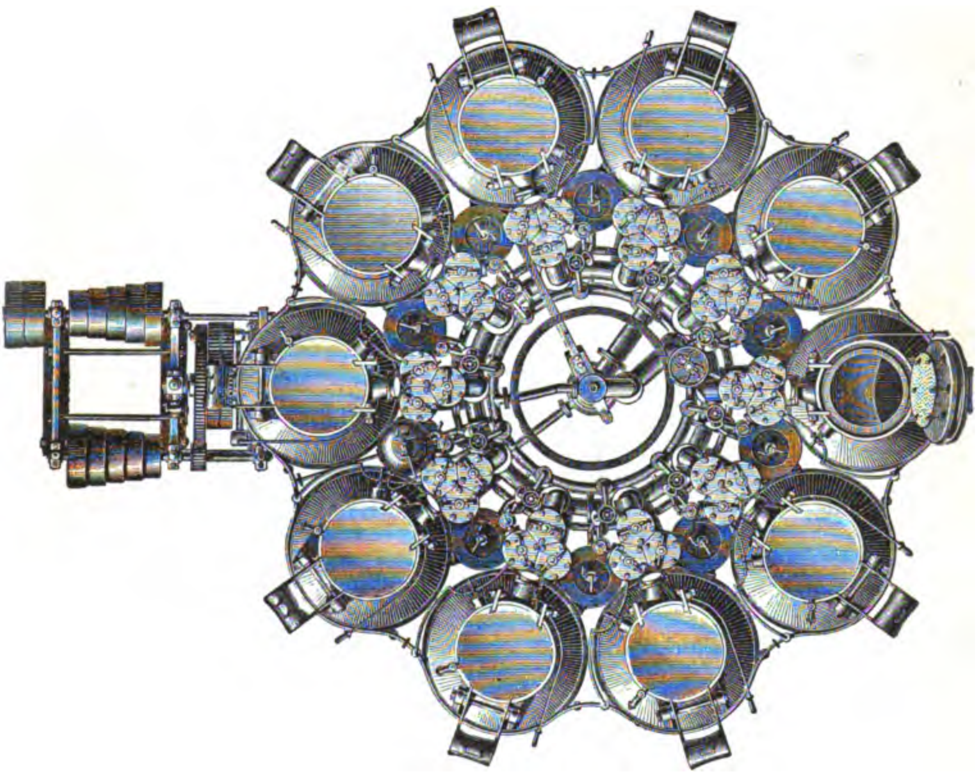

FIG. 110.—Plan of Rotating Diffusion Battery.

In this manner these vessels may be filled with cossettes without handling and with great cleanliness and rapidity.

The diffusors may be said to consist of three parts, the upper, middle and lower. The upper part can be opened or closed in a very few seconds, and the exit of the air is effected through a small opening in the head. The lower part of the diffusor is shaped for rapid emptying; the exit doors also are of large size,

and their closing or opening is accomplished with ease. A rubber water joint used here has given satisfaction.

The diffusors may be all connected, or water and juice introduced into any of them by separated valves worked from above. The circular connecting pipe has valves that are all alike.

This apparatus has a maximum capacity of 250 tons per day of 24 hours. The juices worked are very diluted and only four hands are necessary to run the machinery. The cubical content of each diffusor is 16 hectoliters, the vessel being supported by suitable frames rotated by a well-combined gear wheel as shown in the accompanying illustration.

Strange as it may seem the mechanical arrangement is such that only 1 H.P. is necessary for the rotation. One most important feature of the apparatus is that the slicer is placed directly over the diffusor, so that the cossettes are equally distributed in the interior. The valves of the battery may be opened and closed from an upper platform. The axis of rotation of the apparatus is used to conduct both steam and water. The upper covering of the diffusor is balanced so that it may be very easily opened. The emptying is attended to by an assistant on the main floor and the exhausted pulp falls into a cemented vault.

Circular diffusion batteries upon general principles present the enormous advantage of being easily operated and looked after. Without changing position the superintendent may ascertain exactly what the working conditions are. He can see at a glance the indications of all the gauges and the position of the valves. Another battery shown in Fig. 111 is the CAIL arrangement which is much simpler than the one described above. Instead of the whole battery only the upper distributing hopper revolves. The exhausted cossettes fall into a receiver at the bottom of which is a spiral, and the product is subsequently carried to an upper floor where it is pressed. Among the disadvantages of the circular battery may be mentioned the great loss of space in the centre of the apparatus. For very small batteries intended to handle 250 tons of beets per diem this perhaps does not have any material significance, but for larger plants working 400 to 500 tons in 24 hours it is quite a disadvantage. Another drawback is that the facilities necessary for the removal of the residuum cossettes are more expensive and troublesome than they should be, and, furthermore, it is most difficult to increase the total capacity of the battery without a large money outlay, as all the pipings and connections would have to be

renewed and the positions of the distributing hopper and the slicer changed to a higher level. If the number of diffusors in the circle has been augmented the diameter of the cluster taken as a whole

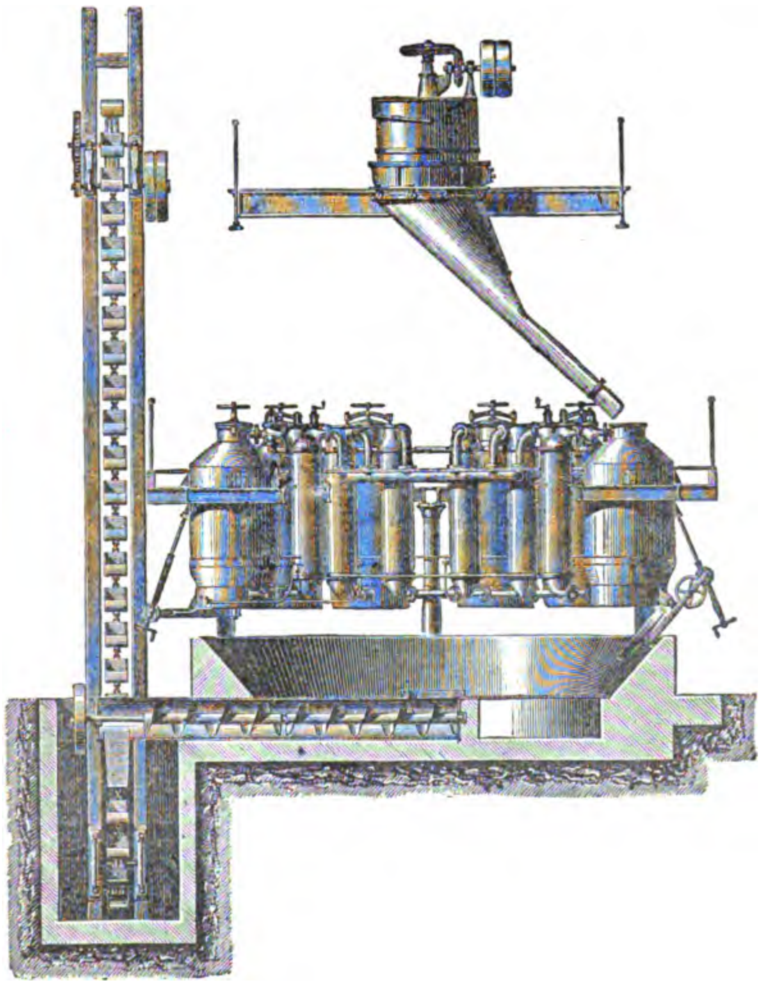

FIG. 111.—CAIL Circular Battery.

must also be greater, otherwise the distributing hopper cannot properly feed the diffusors with the beet slices. A method that has met with some success consists in simply placing a few additional compartments within the circle formed by those already existing. In

this case one man can generally take charge of the entire work, which is not possible when the four or six additional diffusors are placed outside of the circle already formed, as numerous complications are presented in filling and emptying the new series. Fig. 112 shows a plan of the MAGUIN arrangement. Only two diffusors

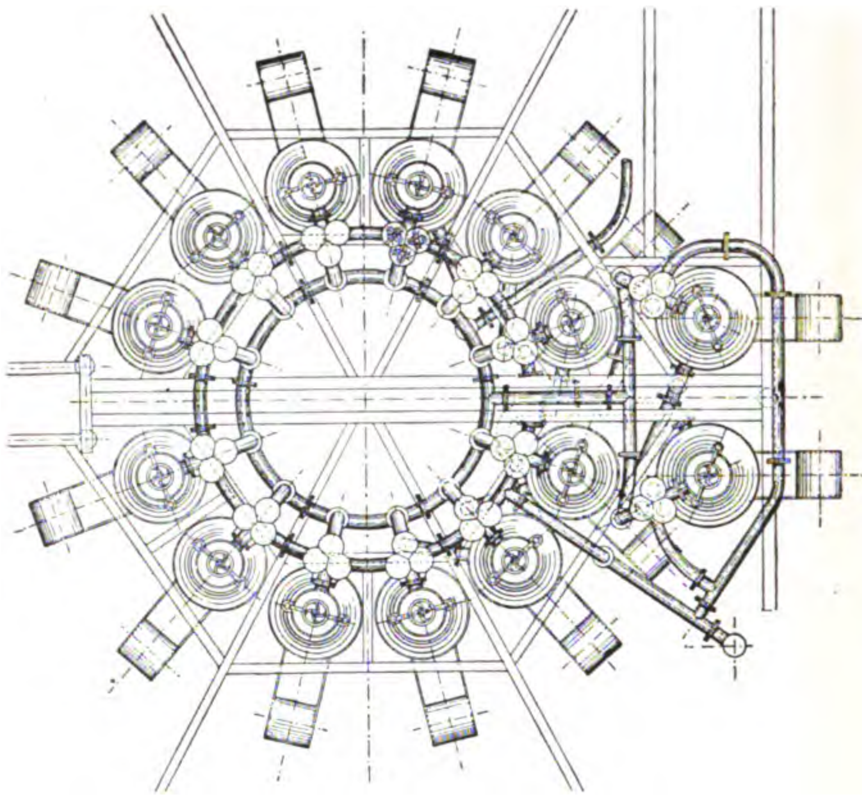

FIG. 112.—MAGUIN Method of Adding Diffusors to a Circular Battery.

have been added, yet the pipe connections become very much more complicated, and the same may be said of their practical handling.

**Straight-line batteries.**—Most of the European beet-sugar factories have adopted the double straight line battery, the residuum cossette carrier being placed between them. When the piping and valve connections are arranged between the rows these batteries are readily supervised, though the battery man has to move back and forward rather more than in the circular arrangement. One of the great advantages of this type of batteries is the possibility

of increasing their capacity by adding the requisite number of diffusors to meet any emergency. In the straight-line battery of the French type (Figs. 113 and 114) the distribution of juice,

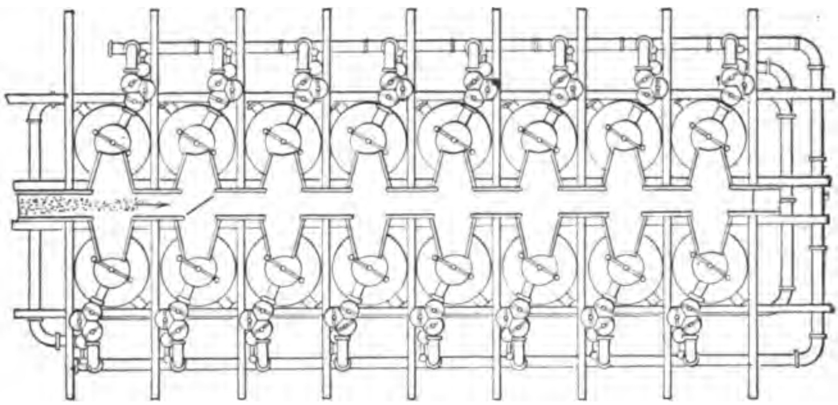

FIG. 113.—Top View of a French Double-line Battery.

etc., is under the control of three-way valves. The residuum cossettes fall into cemented receivers divided in two sections and the distribution of fresh cossettes is accomplished through a horizontal band carrier. The hopper connecting with the diffusor has certain important characteristics as shown in the illustration.

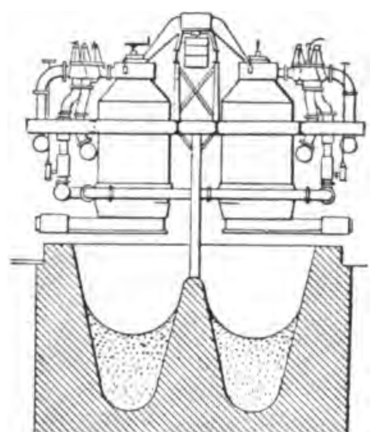

FIG. 114.—Section of Double-line Battery, showing Cemented Residuum Pulp Receivers.

In the German arrangement (Fig. 115) *E, E, E* are the calorizators and *B* the movable distributing hopper receiving its slices from the horizontal carrier. The diffusors are held in position by the girders *D, D* and emptied directly from the bottom. In a diffusion battery there are numerous accessory appliances, such as thermometers, pressure gauges, and complicated valves, cocks, pipings, etc. The thermometers attached to the calorizators or to the connecting pipes should be protected by a suitable grating. The scale of the mercury column should be very wide and be

placed in a position so that it may be readily read from a distance. Before the beginning of each campaign the accuracy of the thermometer should be carefully verified as the temperature of diffusion batteries play a most important rôle and should be constantly watched. It too often happens that it is entirely too low to obtain the desired results. Experts agree that most of the methods for making the temperature determination are very faulty and that the mercury thermometer is the only reliable divice.

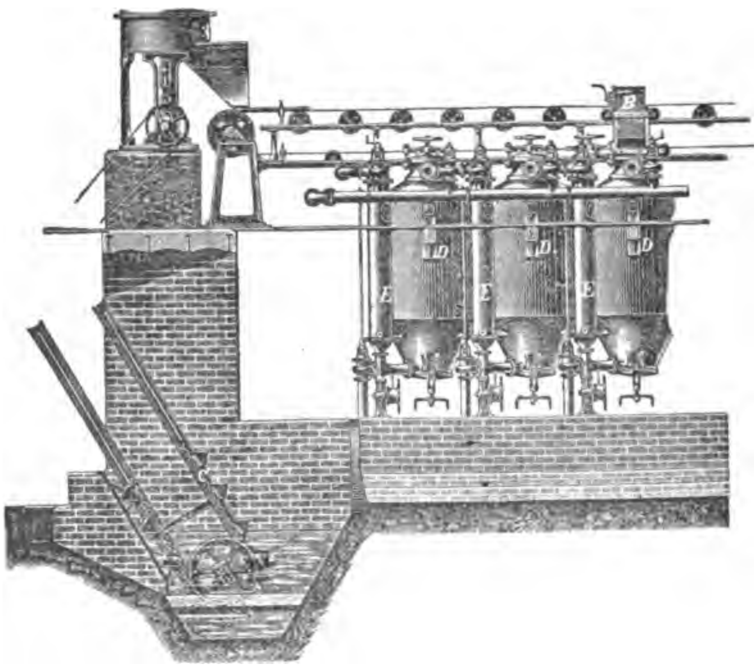

FIG. 115.—Front View of a German Double-line Battery.

**The piping** in all diffusion batteries consists mainly of the water pipes, those that convey the juice to the measuring tanks, those that permit a continued communication between all the diffusors, and the steam pipes for heating. There may be also special pipes for the cold and dirty water, for compressed air, and for steam and vapors of different kinds, such as the exhaust and live steam, and the vapors from the evaporating appliance, for the hydraulic joints, etc. All the double piping for the different kinds of water and the steam may be eliminated by communication between the

main pipes. Precautions should always be taken not to open the valves for live steam and vapors from the first compartment of the evaporating appliance at the same time. The piping for the compressed air communicates with the water pipe connecting the diffusor by means of a series of pipes with valves.

Piping and valves of considerable dimensions are in most cases very desirable for a satisfactory circulation, although in some cases too much importance is attributed to their influence. When the velocity of the juice in the pipes does not exceed 1 to 1½ meters per second there can be no special advantage in increasing the diameter of the pipes and valves. A poor circulation has determinable causes which should be ascertained. One important consideration not to be overlooked when making the calculation relating to sizes of pipes is that of their capacity. There are always certain inactive portions, and while exceptional sizes may be desirable for the circulation of the juice they are not advisable when considered from the standpoint of exhaustion and the concentration of the juice.

The operation of diffusion necessitates constant pressure and should be accomplished as rapidly as possible. Efforts have been made to reasonably reduce the time consumed in complicated valve manipulation. Breitfeld and Danek have recommended the use of valves with lever attachments by which they may be instantly opened or closed. This plan, illustrated in Fig. 116, offers the advantage of permitting one to ascertain by a rapid glance whether the position of all the valves is correct. The rod of the valve passes through a stuffing box. When the lever is horizontal the valve is closed, when vertical it is open. In order to obtain the vertical position the wedging of the lever is slightly set back, so that when the valve is entirely opened the lever is out of plumb and off of its centre of gravity. The counter-weights are flat and may be painted in colors indicating their function, for example, red for water, white for juice, etc. As before mentioned, owing to the special fiscal laws in certain countries the requirements for rapid working are not only very exceptional but interesting.

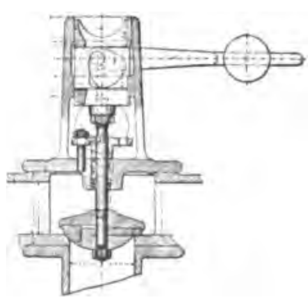

Fig. 116. — Breitfeld and Danek Lever-valve Combination.

The Kodl * valve (Fig. 117) is held by a rubber band *k*. When water is introduced through *f* the band settles and prevents the

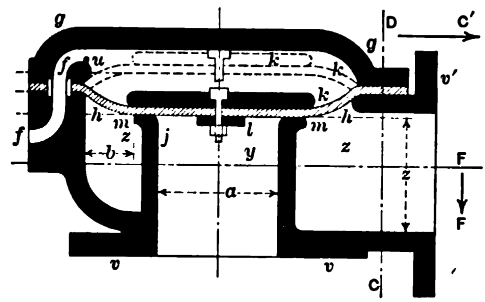


Fig. 117.—Kodl Hydraulic Valve.

passage of the liquid. The dotted line shows the position of *k* when up and the full line when down. By removing the water the valve is opened. This operation is so simple that all the valves

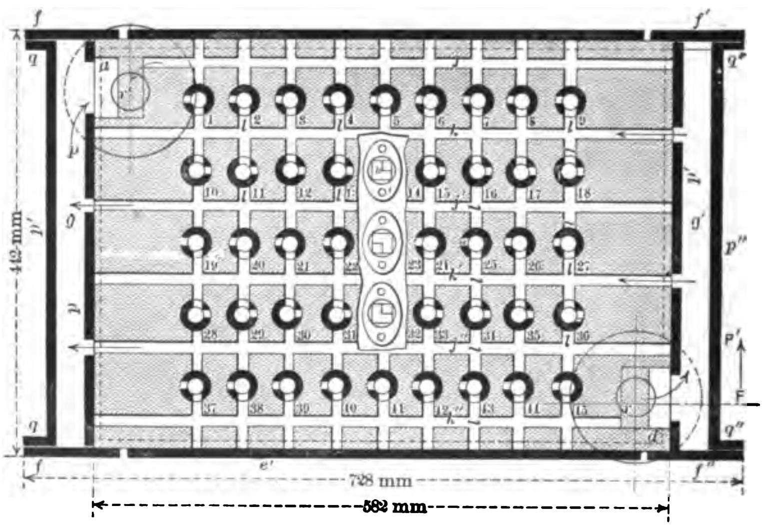


Fig. 118.—Plan of Central Station for Working all the Hydraulic Valves of the Battery.

may be controlled by one person by means of a keyboard (Fig. 118) placed at the centre of the battery. Even the emptying doors of the diffusors may be operated in this way. A series of three-way

* Oe.-U. Z., 9, 304, 1880.

communication cocks which control all the valves is placed on this table. Each one has its individual number indicating the work it is to do. It is difficult to understand why this idea was never practically introduced, but after several Austrian factories gave it a trial it was abandoned.

The valves generally used are those with double-thread screws. Such valves are opened wide by three or four turns. The pitch of these screws should not be excessive, as is often the case, as the valves then open themselves. Preference in most factories appears to be given to valves with movable keys which the battery man displaces after each manœuvre. When the next manœuvre is to be made there is no danger of making a mistake regarding the key to be used, as such valves have left-handed screw threads, and when the key takes hold of the nut the screw-threaded rod rises in the centre. Under these conditions they are turned like the ordinary valve and rise or fall as the case may be, the dangers of making a mistake being thus considerably lessened. From time to time other valve combinations have been suggested, such as an arrangement which allows only one valve to open at a time. This plan was intended to prevent all false manœuvring, but owing to their cost or complicated construction they have never been generally introduced. As the rod of the movable key valves rises several centimeters when the valve is opened it is possible at a glance to determine the position of all the valves. Many diffusion batteries, however, have simply ordinary valves with hand wheels. All valves should be kept in perfect condition so as to prevent the mixing of liquids and sugar losses. As a general thing only valves with hard rubber obdurators are used, as before the campaign commences these allow free escape of the interior liquid, but after the battery has been properly tested they again become tight. If after one or two days' use they are still leaky they must be renewed.

**Material for piping.**—As has already been explained, copper was formerly preferred for piping as it offered many advantages for adjusting, etc., but it was soon found to be too expensive, and, furthermore, it is attacked by the sweet diffusion juices and requires frequent renewals. For the vertical pipes forged iron is used but for all others cast iron answers the purpose.

### WATER FOR DIFFUSION.

**Volume of water.**—One of the first essentials for the satisfactory working of diffusors is evidently the use of soft, pure water which holds but few foreign substances in solution. A calcareous water need not necessarily be put aside in case of an emergency, but one that is abnormally alkaline should be rejected. If soft, pure water cannot be had the quality and the purity of the juice will always suffer, especially in factories where the lack of water is so great that the decanted residuary water in which mineral and organic substances are dissolved must be used for diffusion purposes.

A large volume of water is needed and when impure water is used the impurities accumulate in the after-products and will necessarily prevent the crystallizing of the sugar. In most cases the condensed water from the evaporating appliance is used for the diffusion battery. These waters are very pure as regards saline constituents, but from causes to be subsequently explained they contain an exceptional amount of ammonia. This offers no difficulty so far as the general working of the diffusors is concerned, for during the concentration of the juice it is entirely eliminated, but it appears to have a certain action on the tissue of the beet. On this question authorities differ. According to HERZFELD, the use in a diffusion battery of water containing ammonia tends to give purer juices than ordinary water, but the saline percentage is slightly increased. It is recommended when using such water to submit it to a preliminary saturation with fluorhydric acid,* under which circumstances fermentation in the battery and the resulting sugar inversion would be obviated.

KRUEGER † very correctly states that during diffusion the same water of condensation from the evaporating appliances, triple effects, etc., cannot be used indefinitely as it finally becomes so charged with ammonia that serious perturbations follow during the work. It sometimes happens that this water is sufficiently alkaline to neutralize the natural acidity of the diffusion juices. Waters of such alkalinity necessarily dissolve a portion of the beet tissue, mainly the organic substances, such as pectine, etc. These substances which cannot be eliminated give, with their

* D. Z. I., 25, 585, 1900. † D. Z. I., 27, 891, 1902.

products of decomposition, certain salts which diminish the commercial value of the sugar. Furthermore, the residuum cossettes whose tissues are attacked under the conditions named become soap-like in texture, are very difficult to handle in the pulp presses and are very much less nourishing when fed to cattle as the water in question removes a portion of the nutritive substance which they originally contained. Diffusion juices which are the outcome of the excessive use of such water are very dark in color, nearly black. The albumin they contain will not properly coagulate even when boiled, notwithstanding that the percentage of these albuminoids is very much higher than in normal juices which are gray in color. In order to bring about a coagulation of the albumin in such cases the juices should first of all be made acid; then only can the albumin when hot pass into an insoluble condition which will in a very moderate degree be influenced by the lime used during defecation. Another authority goes so far as to declare that diffusion juices obtained with strongly alkaline waters are most difficult to work in the pan, as the boiling appears to stop during graining.

From another standpoint BOSSE * recommends the use of hot ammoniacal water in diffusion. This hot water economizes fuel and the residuum cossettes submitted to its action will be readily pressed after leaving the battery. MUELLER † declares that if in diffusion batteries there is water of 45° to 50° C., consisting of a mixture of 8 parts ammoniacal water and 2 parts cold water, it is possible to obtain a very superior juice from the diffusor. Very little steam need be used. Under these circumstances he states that the resulting residuum cossettes contain 12.6 to 16 per cent dry substances, and the efficiency of the cossette presses is increased 15 to 20 per cent. It is claimed, furthermore, that the cossette dryers use less fuel and work more satisfactorily than is possible with the residuum from a battery worked by the usual methods.

**Hot water.**—The use of hot water, such as the condensed water from the condensor, that which has been condensed in the triple effect, or water that has been heated in special reheaters receiving their caloric from the fourth compartment of an evaporating apparatus, economizes steam and effects an important economy. If ammoniacal water is used in the battery it is already hot, but when river or well water is used it should first be

* D. Z. I., **25**, 322, 328, 1900. † Z., **51**, 193, 1901.

heated. The most important effect of hot water upon the battery is that the diffusors forming the end of the series, which should have the highest temperature, can the sooner reach the desired temperature. According to Melichar * the principal advantage of hot water in the diffusion battery is that it permits the use of fewer diffusors to attain a given result, because hot water has a more rapid action than cold upon the beet slices. Under no circumstances, however, should hot water be used unless it may be heated without expense by some of the various ways nearly always existing in beet-sugar factories. Such heat is furnished when condensation water is used. Reheating when necessary is effected in a reheater placed between the last compartment of a multiple effect and the condensor.

Horsin Déon adopts an interesting method of obtaining hot water for the diffusion battery, which consists in pumping it from a triple effect into a closed receptacle communicating with the water-pressure tank. As the pressure of the pump is greater than that from the tank, all the hot water is absorbed by the diffusion battery and the cold water subsequently mixes in the collector in the required proportion. The cold water coming in contact with the hot will precipitate the calcareous substances in solution which are thus kept out of the diffusors and the work that much improved.

**The extreme limit of temperature** of this water is that which is required in the diffusion battery, that is to say, about 80° C., but only in exceptional cases is such a temperature employed. Even a limit of 50° C. in the end diffusor would have practical disadvantages if the battery men empty the diffusors, as their hands would be scalded in handling such hot cossettes. In some factories manual labor is entirely done away with for the emptying, in others the precaution is taken to cool the cossettes before they leave the diffusors. To obviate this difficulty it is proposed to have two separate water pipes connecting with the compartment, one of which contains hot and the other cold water. Just before the juice is run off the cold water is used. But when the diffusors have direct bottom-emptying appliances, or when the emptying is effected by compressed air the temperature may far exceed 50° C.

Some authorities claim that the water to be used for diffusion should not be heated to more than 30° to 35°. By using the Blancke valve (Fig. 119) hot and cold water may be mixed. Two

* B. Z., 25, 8, 1900.

pipes conduct water to this valve and empty their contents at a certain point into a common pipe leading to the battery. The sluice valves are connected with the same handle and the arrangement is such that the wider the one is opened the more tightly is the other closed. By the use of a thermometer placed on the mixing pipe the temperature of the water may be regulated with considerable accuracy. STENTZEL * says one of the advantages of this mode is a considerable saving in calories. The cooling water of the condensors may be used, but if too hot it is better to resort to cold water.

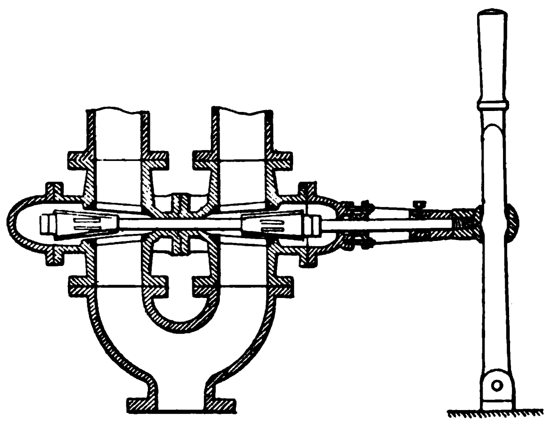

FIG. 119.—BLANCKE Hot- and Cold-water Mixing Valve.

**Quantity of water.**—As previously noted, an ample water supply must be available for the proper working of a diffusion battery. The water lost during emptying, that needed for drawing off from the diffusor, that used for its washing, etc., amount to a total volume representing 250 per cent of the weight of the beets sliced. Some economy of water may be desirable in special cases, but experience shows that not less than 130 per cent of the weight of the beets is admissible. POKORNY † estimates that the volume of water for diffusion is 264.7 per cent of the weight of the beets.

**Pressure in Battery.**—The resistance offered to the water circulating in the diffusors depends upon the thickness of the beet slices. The battery itself exerts an important resistance. In the LIZERAY ‡ experiments it was shown that the resistance of the battery and that of the beet slices are in the proportion of 7.80 : 6.15

* C., 7, 83, 1898. † B. Z., 20, 541, 1896.
‡ Alcool et Sucre, Vol. 11, p. 75, 1893.

when the thickness of the cossettes is 4 mm. If the thickness is decreased to 3 mm., the proportion becomes 3.91 : 10.07. Under these conditions the velocity of the moving juice falls in the proportion of 0.0547 : 0.0276. It is, therefore, evident that the water pressure must be increased or decreased according to the thickness of the cossettes in order to attain the normal efficiency of the battery.

The resistance offered by the cossettes has been made the subject of special investigations of F. Lizeray. The height of the water-pressure tank used was 14 meters and the temperature of the five last diffusors 75° C.

RESISTANCE OF BATTERY AND COSSETTES.

| Conditions of Test. | Time for Running 18 hl. into Measuring Tank. | Output per Second. | Velocity at Exit Opening, $S=0.0104$. | Height Corresponding to this Velocity, $h=\frac{v^2}{2g}$. |
|---|---|---|---|---|
| | Seconds. | Cu. M. | M. per Second. | M. |
| Empty. . . . . . . . . . . | 125 | 0.014400 | 1.385 | 0.0978 |
| Cossettes of 4 mm. . | 167 | 0.010780 | 1.036 | 0.0547 |
| " " 3½ " . . | 202 | 0.007906 | 0.759 | 0.0293 |
| " " 3 " . . | 235 | 0.007660 | 0.736 | 0.0276 |

If $R$ is the resistance of the battery when empty, $H$ the charge from the water tank, $h$ the height corresponding to the velocity $\left(\frac{v^2}{2g}\right)$, then $H=R+h$.

In these investigations $H=14$ meters, $h=0.0978$, the output $Q=14-0.0978=13.9022$ meters, so that the battery even when empty offers an important resistance. $Q$, which was 0.0144 per second, becomes smaller when the diffusors are full of cossettes. If $C$ is the resistance offered by the cossettes, $R'$ the new resistance offered by the battery, $h'$ the height representing the velocity $v'$ of the juice, one would again have $H=R'+C+h'$.

A series of calculations leads to the following table:

RELATION BETWEEN RESISTANCE OF COSSETTES AND OF THE BATTERY.

| Conditions of Test. | Height Corresponding to the Velocity in Meters $=h'$. | Actual Resistance of the Battery $=R'$. | Resistance of the Cosette $=C$. |
|---|---|---|---|
| Empty. . . . . . . . . . . . . . | 0.0978 | 13.9022 | 0.000 |
| Cossettes of 4 mm. . . . . | 0.0547 | 7.8000 | 6.1453 |
| " " 3½ " . . . . . | 0.0293 | 4.1800 | 9.7997 |
| " " 3 " . . . . . | 0.0276 | 3.9100 | 10.0724 |

This table shows that as the resistance of the cossettes increases the comparative resistance of the battery decreases. Other calculations show that the resistance increases with the height of the diffusor and decreases with its diameter.

The pressure necessary to overcome the resistance offered by the beet slices to the circulating juice will also vary with the length of the battery; ¾ to 1½ atmospheres may be considered a reasonable limit. Allowance must also be made for the height of the measuring tank in adjusting the pressure. If it is higher than the battery the pressure should be correspondingly increased; if lower, diminish the pressure proportionately. The latter arrangement is adopted for long batteries.

SEDLACZEK * recommends that the juice drawn off be run into a closed measuring receptacle which is put in communication with a reservoir from which the air is exhausted. Experience appears to show that this arrangement increases the efficiency of the battery and offers important advantages over the system of placing the air pump in direct communication with the closed measurer, as the vacuo rises more rapidly in the measurer and the pump works with greater regularity. To the tank connected with the air exhauster the air-purging cocks of the diffusor may be attached. The ultimate quality of the juice is better for the reason that it does not oxidize in contact with the air.

The counter pressure of the measurer may be lessened by a suction pump placed upon the pipe connecting the measurer with the diffusion battery. This arrangement, however, gives satisfaction only under special circumstances and may even become objectionable, if the pump is too powerful, by forcing the air into the diffusors. For this reason and on account of the expense involved centrifugal pumps have now been generally abandoned in such cases. The increase of the water pressure upon the last diffusor also has a doubtful effect as soon as the standard 10-meter height between the reservoir and the measurer is exceeded. The velocity of the circulating juices increases according to a well-known law, that is, with the square root of the pressure. Furthermore, all excess of pressure increases that of the cossettes upon the perforated bottom. With hard and firm cossettes this is not objectionable, but if the cossettes are fine and soft serious complications may follow. The remedy is without effect just when it is most needed.

* C., **10**, 817, 1902.

**Pumps and water reservoirs.**—The water used in the diffusion battery may be forced directly into the diffusors by means of an ordinary pump, or brought under pressure from an elevation 8 to 15 meters above the battery. Direct pumping is certainly not desirable, but satisfactory results may be obtained with a double-acting pump, though with all possible care their action is not sufficiently regular to prevent the repeated hammering of the pistons, which cause the cossettes to settle in the reservoirs, thus forming obstructions to be overcome by the circulating juice.

The water pressure may vary with the general arrangement of the factory and with the degree of fineness of the cossettes. The most interesting experiments relating to the height of the water tank above the battery are those of BARBET, who showed that if the pressure of the mercury column was 63 cm. when the juice was drawn off to be sent to the measurer the pressure in the diffusor was 57.5 cm. Consequently there exists in the water tank in full pressure a charge of only 0.724 meters, and this is sufficient to force the juice to circulate. In theory the height of the water tank is not constant, but should vary with the resistance offered by the cossettes. If the tank is stationary the cossettes are not properly exhausted, and the only way to overcome the difficulty is to regulate the flow of juice drawn off to be sent to the measurer so that it will be the same per second, calculating it from the diameter of the diffusors. The velocity of the circulating juice in the battery should be constant. The height of the water tank is such as to allow for the worst possible condition that may be presented. HORSIN DÉON in discussing the question says that there should be placed upon the pipe connecting the water tank and the battery a special cock which will not allow the flow of the liquid a greater velocity than has been determined upon in advance. This makes it possible to have the desired circulation in the battery whatever may be the pressure from the water tank. This expert states that he has found it advantageous to do away entirely with the pressure water tank and to substitute a pump with regulator attachment. On the pipe connecting with the battery is a cock that works as explained above. With such an arrangement there need be no apprehension as to whether the water in the tank is frozen or not.

HERBST * claims that the water pressure may be regulated by

* B. Z., 25, 539, 1900, 1901.

the use of a LAVAL turbine revolving at a velocity of 30,000 revolutions per minute. When the turbine is placed in the water pipe a sudden closing of the valve would allow an increase in the pressure of not more than 25 per cent. Under these conditions a reservoir to regulate the water becomes useless and may be replaced by a simple valve, notwithstanding the increased pressure. The cossettes no longer offer an abnormal resistance and the juice circulates freely. In most cases, however, it is customary to pump the water into a reservoir connecting with the battery. The pressure thus obtained is always about the same. When a pump is used the pressure varies with the resistance of the cossettes, but may be increased by special charging of the safety valve.

**Steam** used in a diffusion battery may be obtained from different sources. In the beginning of the campaign the only steam available is live steam or the exhaust. The heating of the battery may be accomplished with the vapors from the multiple effect employed when the apparatus is in full activity. This vapor costs very much less than live steam and is used in the calorizators, but for injection live steam must be used.

**Quantity of steam.**—MELICHAR * estimates in the following way the quantity of steam needed for diffusion:

Average temperature of fresh cossettes 16° C.,
" " " water in battery 30° C.,
" " " the exhausted cossettes 33° C.,
" " " " residuary water from battery 33° C.,
" " " " diffusion juices 30° C.

He estimates that from 100 kilos of beets 240 kilos of exhausted cossettes and 110 kilos of diffusion juice are obtained. It is supposed that the reheating is done with injectors at a pressure of four atmospheres. These are lost in the exhausted cossettes and the residuary water $204 \times 3 = 612$ calories. The reheating of the fresh cossettes from 16° to 30° demands $100 \times 14 = 1,400$ calories. The steam consumption is $\frac{2012}{653-33} = 3.3$ kilos.

There is, however, another source of steam consumption which is loss through radiation. The diffusors, calorizators, their piping, etc., collectively represent considerable surface through which heat may be lost. The experiments of POKORNY † in this

* B. Z., 18, 302, 1894.

† B. Z., 22, 429, 1898.

respect lead to some important conclusions. The loss per 100 kilos of beets sliced per hour in a small battery of 13 diffusors of 1880 liters capacity each was about 576 calories, or about 1 kilo of steam per hour, and this loss is necessarily very much greater for a larger battery. Hence the importance of covering the diffusors, calorizators, and piping with some non-conducting substance as is done in many factories. The heat losses in a diffusion battery are mainly the outcome of the number of calories that the exhausted cossettes and the residuary water from the diffusors carry away. On this point CLAASSEN and MELICHAR do not agree. The former maintains that the temperature of the water used in diffusion has an important influence on the heat losses. Under no circumstances should the water for the battery be heated from a source that could be otherwise utilized, for this would mean an absolute loss as the residuary water upon leaving the battery is still hot. It is without doubt a great mistake to excessively heat the last diffusors and calorizators by a great expenditure of steam, as this would simply heat further the cossettes that are thrown out, while if the first diffusors of the series are heated the caloric furnished will be carried out by the juice and represents an ultimate saving. There is ample authority to show that the early heating yields purer juices.

## WORKING OF A DIFFUSION BATTERY.

The working of a diffusion battery is hardly ever the same in any two factories. The main characteristic points of resemblance are the intermitting phase of the operation, the reheating of the juice between the diffusors and the nature of the juice circulation. The juice circulates in all diffusors from top to bottom, and it is only in the diffusor recently filled with fresh cossettes that the circulation is in the reverse direction for the purpose of driving out the air. All the other features, such as the temperature, the length of the operation, and the concentration of the juice, vary a great deal. As the size of the diffusors and the kind of beet slices or cossettes are very different no special directions can be given, and rules that would be applicable to every case cannot be established; but there are certain general principles by which every factory would do well to be guided.

There is, however, one way of working that may be considered classical and should be followed as all the existing modes are

simply modifications of it. The cossettes are distributed in the diffusors in various ways, as has been previously described. If allowed simply to fall by gravity there would be only 45 kilos per hectoliter capacity, and 57 liters of free space would consequently remain to be filled with juice. This condition is not desirable as those interstices are a waste as far as the efficiency of the diffusor is concerned. Theoretically the water should never be able to find any other passage than along the surface of the beet slice. From this point of view there is every advantage to be gained by forcing the cossettes to settle as much as possible, but this must evidently not be pushed to an excess, as not only would the juice be unable to circulate, but the emptying of the residuum from the diffusor would be most difficult. In some factories it is customary for the battery man's assistant to press the beet slices down with his feet. This need only be done, however, when the diffusor is nearly full. During the filling it may be found desirable to use a long pole with which the cossettes are pressed well against the sides.

**Flow of juice in the diffusors.**—In order to intelligently follow the working of a diffusion battery one must understand the differ-

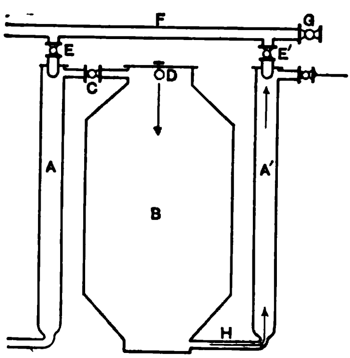


FIG. 120.—Flow of Juice, Tail End of Battery.

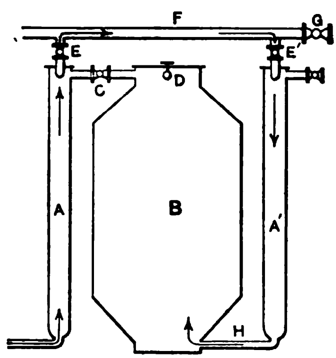


FIG. 121.—Flow of Juice during Mashing.

ent circulations of juice in the diffusors. Into the last one of the series water enters through the valve $D$ (Fig. 120), flows through the mass of cossettes, and then rises through the calorizator $A'$, after having dissolved a small percentage of sugar and becomes thus transformed into what may be called juice. This liquid then passes into the second diffusor through which the flow is exactly the same, and thus continues its journey through the other com-

partments of the series. If a diffusor at the other end of the battery has been recently filled with beet slices it must also be filled with juice. The juice could readily enter through the valve $C$, but for special reasons this is not permitted, and it is made to flow through the calorizator $A$ (Fig. 121) and the valves $E$ and $E'$ connecting with the piping $F$. The valve $G$ being closed and $E'$ open the juice flows in a downward direction through $A'$ and $H$ and enters the diffusor $B$. This special flow is called mashing, from the German "maischen."

When the liquid is drawn off, the diffusor being full of juice, the flow in the latter is reversed (Fig. 122). The valve $E$ is closed while $C$ and $G$ are opened. The juice from the preceding diffusor passes through $A$, the valve $C$ and diffusor $B$, then through $H$ and the calorizator $A'$ and is forced through $E'$ and $G$ into the measuring tank.

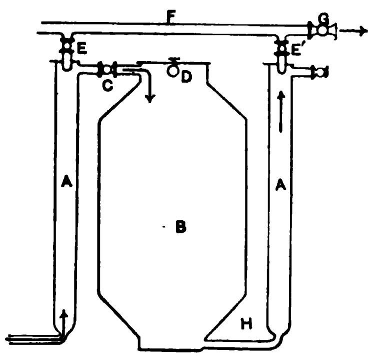

FIG. 122.—Flow of Juice during Drawing Off.

**Flow of juice in the battery.**—If the battery is considered as a whole the juice circulates as shown in Fig. 123. The water valve $w_5$ is open and allows communication with the diffusor $D_5$. After having passed through that compartment from top to bottom the juice runs through the calorizator $C_5$ into the diffusor $D_6$ and, passing through beet slices contained there, runs through $C_6$ into the following compartment, and so on until reaching $D_n$, when it rises in the calorizator $C_n$, flows through the valve $c_n$, and into the pipe $F$, to enter the diffusor $D_1$. The pipe $F$ differs from the other pipes of the battery only in its length, as all are of the same diameter, and its sole object is to provide a continuous communication between the top of the calorizator $C_n$ and the top of diffusor $D_1$. The juice continues its journey through $D_1$, $D_2$, but as $D_3$ has been recently filled with beet slices the valves $J_2$ and $J_3$ are opened and $S$ is closed (in Fig. 121 $J_2$ and $J_3$ are represented by $E$ and $E'$, $S$ by $G$) and the juice rises through the calorizator $C_2$, enters the pipe $G$, and descends through $J_3$ and the calorizator $C_3$ into the diffusor $D_3$ from the bottom. In $D_3$ the mashing is effected, and when full its contents are immediately drawn off. The first thing to be done is to estab-

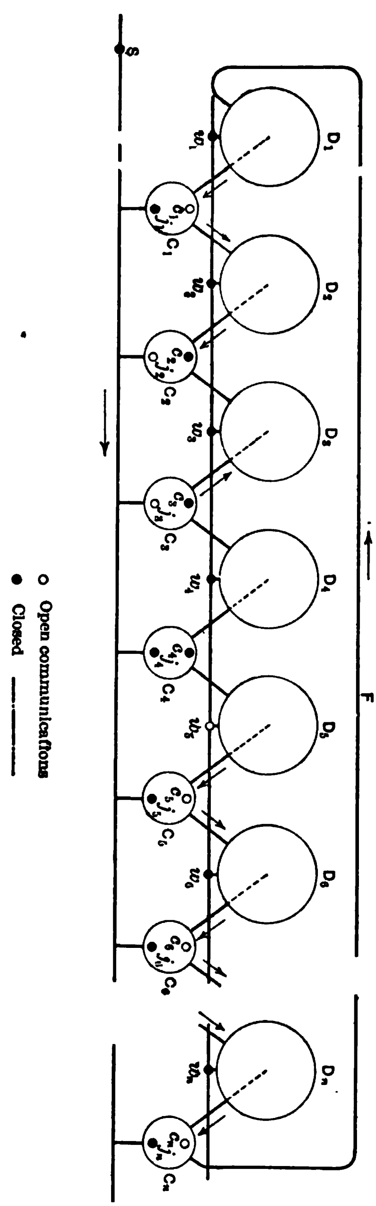


FIG. 123.—Plan of Battery, showing General Circulation of Juice during Washing.

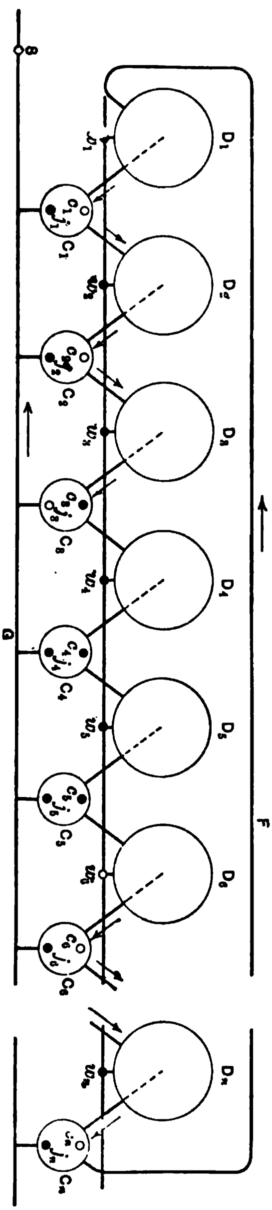


FIG. 124.—Plan of Battery, showing General Circulation of Juice during Drawing Off.

lish in $D_3$ the normal circulation of the juice. To this end $c_2$ (Fig. 124) is opened, $J_3$ closed, and the valve $S$ opened. The juice from the calorizator $C_2$ flows through the valve $c_2$ to the top of the diffusor $D_3$, rises in the calorizator $C_3$, and passes through $J_3$ into $G$ and from there through $S$ into the measuring tank. During this interval $D_4$ has been filled with fresh cossettes. To break off the communication of $D_5$ with the battery when its cossettes are exhausted, water is introduced into $D_6$ through the valve $w_3$, and this diffusor then becomes the last of the series. $D_5$ is isolated by closing the valve $c_5$ and the water valve $w_5$, and having no longer any communication with the battery, it may be emptied.

After the juice has been drawn off the water pressure is upon $D_6$, $S$ is closed, $J_4$ opened so that the juice from the diffusor $D_3$ may flow down through the calorizator $C_4$ into diffusor $D_4$, in order to mash in this diffusor. This operation is continued indefinitely. The same manœuvre is applied to a circular battery, the main difference being in the piping, in which case $D_n$ is side by side with $D_1$, and the pipe $F$ is of the same length as the connecting pipes between the diffusors and the calorizators.

**Necessity of working from top to bottom.**—As has been shown the circulating juice flows from one diffusor to another, and when it has passed through a certain number of compartments its composition is nearly the same as that contained in the beet cells. The volume of juice drawn off corresponds about to the weight of cossettes added to the new diffusor, in other words the quantity of sugar taken from one diffusor is about the same as that added to another in the form of beet slices. The cossettes at the other end of the battery become more and more exhausted of their sugar because they receive water that contains less and less sugar and finally pure water. After the juice is drawn off from one diffusor the emptying of another follows and thus the diluted juice can not mix with the concentrated juice. An interesting fact not to be overlooked is that the weight of these concentrated juices increases the pressure in the battery. On the other hand, the juice becomes less dense in the calorizators owing to the temperature, and thus naturally rises. This phenomenon is an assistance in the general circulation in the battery. When injectors are connected with the apparatus their action tends to force the juice upwards, all of which argues in favor of the circulation from top to bottom.

On the other hand, serious difficulties may present themselves.

If air or gas exists in the midst of the cossettes it cannot rise to the top and escape when the juice is forcing it down, while if the juice was introduced from the bottom the contrary would be the case. It is to be noted in this respect that when gases are present the exhaustion cannot take place because the juices do not come in contact with the beet slices at those centres. Experiments have been made which consisted in changing the direction of the circulating juice in the battery; that is, instead of flowing from top to bottom the juice is forced upward so as to keep the cossettes constantly floating in the liquid and prevent them from clogging or stopping the perforated bottom. But when the cossettes are forced upwards they eventually stop up the small holes of the upper filtering plate, when such exists, just as they do those of the lower plates in the regular modes of working. The circulation from top to bottom is more advantageous for the further reason that by this method thicker juices are displaced by the dilute ones that follow without much mixing.

**Importance of mashing.**—It has been shown that during mashing the juice is introduced from the bottom of the diffusor, and this is essential for the successful working of the battery. If the juice was introduced at the top of the diffusor it would not be satisfactorily distributed through the mass and large quantities of air would remain to prevent the juice from coming in contact with the cossettes; furthermore, if not liberated this might cause great irregularities in the working of the entire apparatus. It is mainly to prevent these complications that the mashing is done. The juice enters at the bottom and rises slowly, forcing out all the air.

Mashing, however, has several objectionable features. When the operation is completed, that is to say when the diffusor is full of juice, the flow is reversed, the circulation then being from top to bottom. As the juice that is at the bottom was the last to form it is the most dilute and is drawn off before the upper, more concentrated juice, which is evidently very illogical. Furthermore, as the juice has circulated through the mass of beet slices, it is cooler on top than at the bottom and has not the same concentration as that in the diffusor immediately following. Notwithstanding these objections, this mode of working continues to be used in nearly all factories.

During recent years many interesting processes have been introduced that in a measure have changed this method of mash-

ing. Bergreen * proposed that a vacuum be made in the diffusors and that the cossettes be heated by a jet of steam. All the air was thus driven off and the juice was brought into thorough contact with the beet slices. But unfortunately it frequently happened that the steam cooked the cossettes and the advantages gained would not compensate for the expense necessitated. On the other hand, the Garez method has attracted considerable attention and has been practically applied in many French factories. The juice is introduced through a special perforated tube placed at the

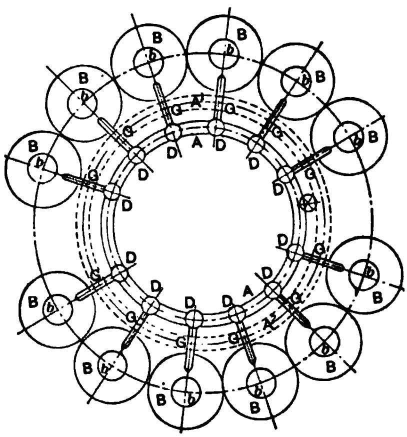


Fig. 125.—Plan of Garez Battery.

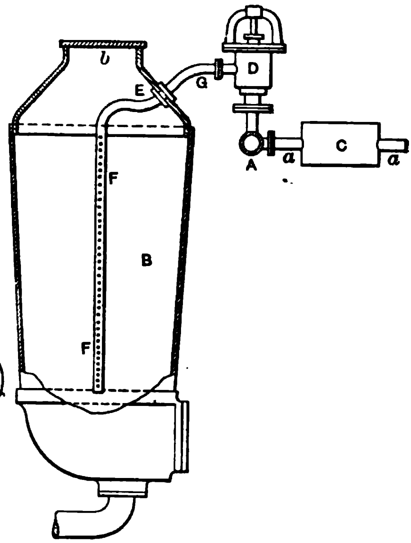


Fig. 126.—Vertical Section of Garez Diffusor.

centre of the diffusor, the compartment at the same time being filled with fresh cossettes from the slicer. When the bottom holes of this juice-distributing pipe are closed by cossettes the flow continues through the perforations at a higher elevation until the diffusor is full. The air no longer offers any difficulties and the temperature of the juice remains almost normal.

In Fig. 125 is shown the general plan of a circular diffusion battery; many of the complicated pipings are only indicated by dotted lines. Fig. 126 is a vertical section of a diffusor considered separately. To the usual piping of the diffusion battery a pipe *A* is added, which is arranged to communicate through several valves

* La. S. B., 27, 381, 1899.

with the diffusors *B*. The pipe *A* is connected by a small branch pipe with the juice pipe *a* at *C*. The juice is heated before it enters the diffusor and after leaving *A* it passes through the valve *D*. *G* connects each diffusor, *B*, with its corresponding valve, *D*, and also with an interior pipe, *E*, which is bent vertically in the centre of the diffusor, as shown in *F*; there is a series of vertical perforations over the entire length of the pipe *F* which does not reach the bottom of the diffusor. When the intention is to fill one of the diffusors the beet slices are thrown in at *b* at the same time that the juice enters through the valve *D*. When flowing through *F* the juice escapes through the vertical openings, the main portion, however, reaches the bottom and soon saturates the cossettes which are being rapidly supplied from the hopper of the beet slicer. As the filling progresses and the bottom of the juice-distributing pipe *F* is covered, the heated juice finds its way through the vertical openings. When the diffusor is filled the conditions are favorable for satisfactory results. The expense is no greater than it is with customary methods of working. During the filling of one diffusor the emptying of another compartment of the series is progressing, communication with *D* being cut off. Practical experiments apparently prove that there follows an immediate uniform contact of the liquid with the cossettes in each diffusor. A high and uniform temperature is maintained from the start and may be regulated at will, under which circumstances the juices are very pure, having been largely freed of their albuminoids, etc. Great economy is also said to be one of the important advantages of the innovation, which may be applied to existing batteries at a very little cost.

**Drawing off of the juice.**—The juice drawn from the diffusor is sent to the measuring tank. There may be two or three of these tanks, but one is sufficient if it is properly managed. The shape varies greatly, but in any case the emptying should be very rapidly accomplished consuming about one-half the number of minutes that elapse in drawing off the contents of a diffusor. If the latter operation takes four minutes then the emptying should consume but two, and, therefore, the section of the emptying pipe is double that of the supply pipe. The tanks are placed either above or below the elevation of the diffusion battery. The volume of juice should be very accurately determined and the battery man should receive ample warning from the man in charge of the measuring tank when the drawing off should cease. An excellent mode consists of an

electrical communication with a float on the surface of the liquid, a bell ringing when the float reaches a certain height. Regarding the various methods of signalling each should have a characteristic sound distinguishing it clearly from all others, otherwise confusion would result. There should also be some attachment by which the exact level may be accurately known.

Open reheaters are used for measuring the juice that is drawn off. The height of the juice in these receptacles is known either through the use of an ordinary floating device or a special signal-control combination, This mode of measuring is very imperfect and cannot be depended upon for exact data. The volume of juice may be recorded approximately by the use of a reservoir with an overflow. The reservoir is entirely emptied each time after having been filled to the overflow, and the volume is determined by weighing an equal volume of water. When this movable overflow system is practically regulated, its results compare favorably with those obtained by many of the appliances now in use, some of which, however, may be strongly recommended.

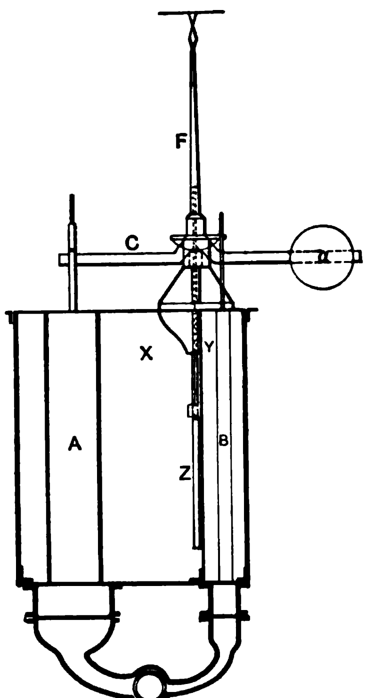

FIG. 127.—CERNY Juice Regulator.

Without doubt a diffusion battery should be worked so that the volume of juice drawn off is proportional to the sugar content of the beets being worked. Several special regulating appliances have been proposed by which it is thought that many of the difficulties hitherto encountered may be overcome. CERNY * has constructed a special apparatus (Fig. 127) intended to regulate the volume of juice drawn off by its density. It consists of a well-balanced scale beam *C*, the equilibrium being obtained by the use of the counterpoise *a*. From this scale beam are suspended two floats

* B. Z., 19, 141, 1894.

*A* and *B*, of different sizes. The larger of the two, *A*, is in one of the compartments of the measurer where the juice is always at a constant level. The smaller, correcting float, *B*, has an influence on the rising motion of the other float, depending upon the density of the juice in which it is placed. The volume of juice entering the apparatus depends upon the power needed to force back the scale beam. When the indicator *F* returns to zero the drawing off from the battery ceases.

Without doubt the composition of the juice during the working of a diffusion battery is very variable from time to time, as it is influenced by the quality of the fresh cossettes run into the leading diffusor of the series; but the regulator above mentioned will modify and equalize the volume and density of the juice drawn off, although the battery may contain beet slices of varying quality. In discussing these appliances it becomes evident that the juice contained in each measuring tank has about the same daily percentage of sugar. The density of the juice depends upon so many circumstances that an effort at special regulation may in some cases be decidedly objectionable, even if the contents of the various diffusors differ in percentage of sugar. It is better to modify the volume of juice drawn off if the sugar percentage of the exhausted cossettes is not standard and cannot be reduced by other means. A regulation through the drawing off should be resorted to only when it is to be continued for some time and may be accomplished by the use of standard measurers. CLAASSEN * states that there is no occasion for regulating the amount of juice to be drawn from diffusors, as beets from many sources are thoroughly mixed during their hydraulic transportation to the factory, and that at any given hour there is not much difference in the average saccharine percentage. When there is noticed a special variation in the quality of beets being sliced, it is possible that still further changes may occur; hence the provision made to meet the difficulty will not be entirely successful. The density of the diffusion juices is mainly influenced by the composition of fresh slices entering the diffusors. A density regulator works at once, and not only when all the diffusors of the battery are filled.

Precautionary means should be taken to draw off all the juice contained in the diffusor so as to avoid certain complications. When the cossettes are not closely packed, it is always possible to

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* D. Z. I., **24**, 1388, 1899.

draw off more juice than when they are well pressed down, but the juice is then more diluted than in the latter case. In many factories it is customary to take the density of the juice after each drawing off, in order to have an average sample of the work done under the best possible conditions, and this mode of control may be of great assistance. In some cases lime is added to the juice in the measuring tank, but this practice should certainly not be encouraged, as it is then difficult to follow the general workings of the battery.

**Heating.**—Whenever a diffusor undergoes the process of mashing, steam is sent into the following calorizator, and in fact in all the calorizators the entrance of steam is so regulated that the temperature of the juice is kept between 78° and 85° C., depending upon the variety of beets being sliced and the rapidity with which the battery is being worked. It is desirable to maintain as high a temperature as possible in most of the diffusors, in order that the cossettes may be thoroughly exhausted of their sugar, but in cases where the battery assistants are compelled to remove the residuum cossettes from the diffusors with pitchforks the temperature in the last diffusor must necessarily be lowered before this can be done. There is no difficulty in maintaining the desired temperature in the middle of the diffusion battery nor in the diffusors at the tail end of the series if hot water is used; but the leading diffusors cannot be heated in the same manner. The juice in its circulation meets cossettes that are colder and colder and its temperature falls proportionately. Efforts have been made to heat these cossettes either by injecting steam or by heating the juice more before mashing.

**Number of open diffusors.**—The number of diffusors in full working activity varies. As a general thing all are closed with the exception of two, one of which is full of cossettes or being mashed, while the other is being filled or emptied. It is customary in large batteries to leave three diffusors open. This has the advantage of providing a reserve compartment that may be needed in an emergency such as arises when the exhaustion is not satisfactory because of semi-frozen beets, etc. In reply to this argument it is said that experience shows that when handling good beets in a large battery better results are obtained if only two diffusors are inactive, and in exceptional cases only one diffusor remains open. This necessitates the use of very large beet slicers, and the machinery must be stopped during the entire period of mashing. In

Austria the filling and emptying of the diffusors is a question of only an instant. However, the number of open diffusors varies as the occasion may demand. In order to bring into working another diffusor a certain interval of time must be allowed if the expected results are to be obtained. After the mashing of a diffusor one at the tail end is thrown out, and after the drawing off still another is cut out. This may be repeated after the juice has been sent to the measurer from the diffusor that follows and the normal mode of working would then commence. For special reasons it seems preferable to work for some time with what is termed a half diffusor, cutting off the last diffusor after the drawing off rather than subsequent to the mashing.

**Emptying.**—As soon as the juices are sent from diffusor $D_3$ (Fig. 124) to the measurer, the diffusor $D_5$ is cut off (Fig. 124) to be emptied, the. water valve $w_6$ is opened, and $c_5$ and $w_5$ are closed. The air is allowed to escape so as to diminish the interior pressure and the emptying door is suddenly opened. If the mass of exhausted cossettes has a tendency to remain in place the emptying door is closed and a certain amount of water is introduced through the valve $c_5$. The exhausted cossettes are subsequently handled in various ways. They may fall upon a moving apron or spiral that carries them to a lift to be raised to the cossette presses. In most straight-line batteries there are two flumes to carry off the residuum cossettes and water. They have a slant of 100 to 120 mm. per meter.

Experience shows that any exterior cement covering is not desirable, for particles necessarily detach themselves and find their way into the cossette presses where they may cause considerable damage. To facilitate the passage of the cossettes into the flumes water is frequently introduced from above at the extreme end of the canal. In circular diffusion batteries the space between the diffusors generally has a slight slant toward the centre where a spiral carrier may be placed. In order to prevent accidents it may be desirable to cover the opening by a suitable grating. When the diffusors are emptied the residuum falls upon the spiral and a certain portion of the water is drained off and is then pumped into the decanting cisterns. An excellent arrangement for circular batteries that has been adopted in Germany is to have the flumes directly under the diffusor, as shown in the engraving (Fig. 128). The slant in the circular flume in

question is from left to right, the section on the right being lower than that on the left.

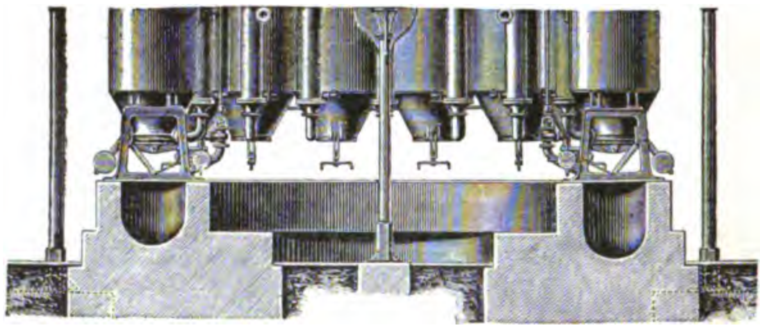

FIG. 128.—Bottom of the Brunswick Circular Battery, showing Flumes for Carrying Off the Exhausted Cossettes.

**Automatic emptying.**—The most important of these methods is PFEIFFER'S,* in which compressed air acts directly upon the upper

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* The director of a factory in which this mode has been introduced, in a letter to the author, expressed himself as follows:[1] "The discharge of the diffusors, by means of compressed air, is accomplished quickly and can be easily supervised. This factory has a battery of 14 cells, of 45 hectoliters capacity each, which are arranged in two rows. The entire installation requires only two men and a boy, a second boy being employed for attending the beet elevator and automatic scale. With these few hands the work is done quickly and satisfactorily. I am convinced that at this station I could easily work 500 metric tons in twenty-four hours instead of the stipulated 400 tons, if the capacity of the other apparatus would allow this increase. The troublesome discharge of the pulp into open gutters, which is the system of the old batteries, and is often a source of discontent with the help, is completely avoided with this new installation. Underneath the battery, which is erected on columns and beams, there is a roomy, clean space, and instead of being, as hitherto, the most unsightly and untidy station in the entire sugar factory, it has become absolutely clean and neat. In addition to this important change, I must mention that the pulp elevator, which requires frequent repairs, and sometimes causes expensive delays, is discarded with this new process, as the air compressor replaces it, and does its work as well and as smoothly as a steam engine.

"With respect to the operation itself, the manufacturer has a great deal of latitude. Nothing having been provided for heating the diffusion water, I used the waste water from the condensor in the beginning, and in this way obtained good results. However, being a staunch believer in *hot* diffusion,

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[1] S. B., June 1902.

surface. As soon as the emptying valve is opened the water mixed with the cossettes has a tendency to run off and to leave the cossettes in the diffusor. In order to prevent the water from running off too rapidly, resulting in an excessive packing of the exhausted product on the perforated strainer of the bottom, the following arrangement is made. An ascending pipe is inserted in the aperture of the outlet of the diffusors. If this pipe is filled with water up to a certain height (about two meters above the diffusor) nothing can leave the diffusor. As long as the valve remains open there is produced an equilibrium of pressure between the inside and the outside of the diffusor; the beet slices on the bottom strainer are raised and floated because the elevation of the column of water is greater than that of the juice in the battery.

Emptying by the PFEIFFER method demands that the ascending pipe should be filled with water up to a certain height before the compressed air forces out the cossettes. This pipe is at first filled with water which may be allowed, as soon as the diffusor is to be emptied, to flow from a valve placed at the bottom of the diffusor. Under these conditions it is possible by the use of hot or cold water to reheat or cool the cossettes in the diffusor according to their condition; furthermore, the residuum may be submitted to chemical treatment before pressing.

If air is introduced from the bottom the cossettes and the water become uniformly mixed and as a result the diffusor is entirely emptied (Figs. 129 and 130) through $F$, the juice leaves at $P$, and the air enters at $E$. The process is based on two principles, counter pressure and bottom introduction of compressed air. Each of the diffusors shown in Fig. 129 is 1.40 meters in diameter, 3.5 in height, with a capacity for 2700 kilos of

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I afterwards made a steam connection with the tank containing the waste water from the condensor. After various experiments I found that an equal temperature of 70° C. in all diffusion cells gave the best results. Under this temperature I succeeded in obtaining an excellent and quick extraction and juices of high purity, combined with the advantage of drawing off only a small quantity of juice. In consequence thereof there is less water to be evaporated, whereby fuel is saved, and as an additional advantage the cost of production is lessened by increasing the factory's capacity.

"To prove the correctness of this statement I would mention that I use only from 8 to 9 per cent of the weight of beets of English coal for producing granulated sugar only, whereas other factories require on an average 12 per cent of the same coal, and some even burn as much as 15 per cent."

cossettes. At two-thirds of the height of the bottom cone a circular cast-iron projection is arranged externally; this is covered on the inside of the diffusor with perforated tin plates which serve as compressed air distributors. At the lower part of the cone is the closing arrangement which may be one of two kinds; the most interesting consists of a cylindrical piston with rubber packing and a tube which inclines and forms an elbow joint or connection. The system is very readily worked by hydraulic

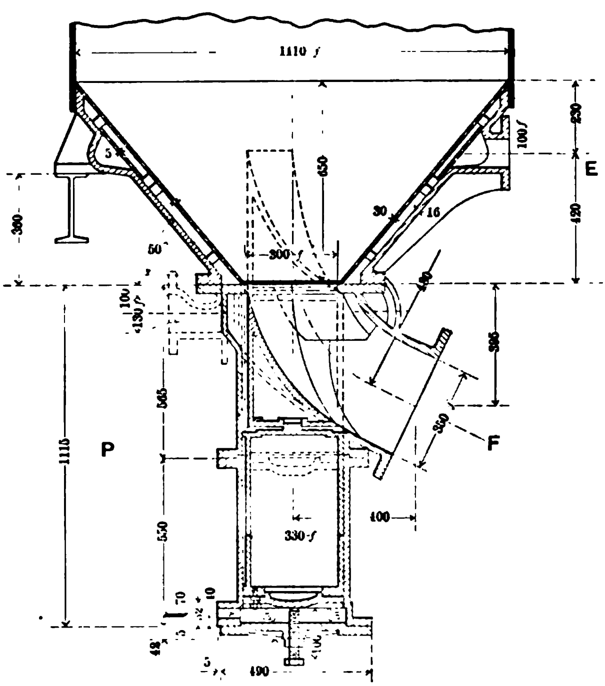


FIG. 129.—PFEIFFER Diffusor, Sectional View.

pressure, the details of which operation are shown in Fig. 131. Water is introduced through $d$, the piston $f$ rises, pushes up the attachment $gk$ into the diffusor, and the rubber joint $h$ effects the closing. This piston is guided in its upward motion by the vertical rod $e$. The opening and closing is done by a pointer placed at an angle of 90°. It has been proposed to substitute for this hydraulic joint a well-compressed fibrous material which, by

means of a special hydraulic arrangement, is pressed against the groove inside the seat of the valve.*

It is admitted by many experts that the so-called cold diffusion with a maximum temperature of 62° C. gives juice of a superior purity, and the percentage of dry matter remaining in the residuum is very high. PFEIFFER declares, on the other hand that such is not the case, but that, on the contrary, in this respect the advantages are in favor of a comparatively high temper-

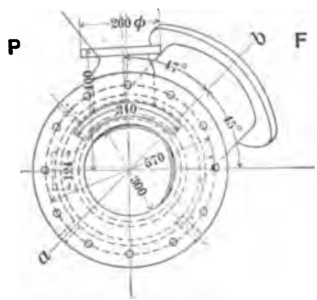


FIG. 130.—PFEIFFER Diffusor, Bottom View.

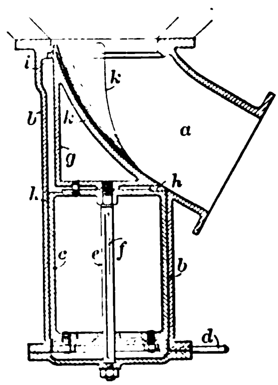


FIG. 131.—Detail of Hydraulic Piston-closing Combination.

ature, 81° C. The yield of *massecuite* and the nutritive value of the exhausted cossettes were then slightly superior to the product from cold diffusion. Apparently there is a theoretical advantage in working by cold processes, but whatever the results they are neutralized by the surplus water needed for working the battery. Recent experiments, considering all the advantages attending the best results, show that the most desirable temperature for working the battery during 1899 varied from 70° C. to 75° C. This temperature demands that the beet slices shall not be exhausted beyond the ordinary limit of 0.3 to 0.5 per cent of sugar, the duration of the operation being considerably reduced. Under these circumstances, the number of diffusors of the battery may be less, and the non-sugar absorption becomes much less, owing to the shortened period of contact of the circulating juice with the cossettes.

The results of the analysis of the *massecuite* show differences.

* Z., 52, 60, 1902.

The average sugar yield for the campaign was 77.3 per cent, as against 76.3 per cent of the previous year, notwithstanding the fact that the beets worked were inferior to those of 1898, which within itself shows the advantage of the process. In a factory working by the PFEIFFER method there are used two diffusion batteries of eight diffusors, six of which are in operation, the temperature being 68.7° C. The PFEIFFER emptying method allows many other very interesting methods too numerous to be mentioned here.

The power of the air compressor used depends upon the height to which the exhausted residuum must be raised. Generally a pressure of 1½ atmospheres is employed. The air compressor has a pressure gauge, and as soon as the desired limit is reached a special mechanical device, working upon the compressor, controls its motion without interfering with the work.

The valve for the sweet water is also opened for a short time, but is closed before communication is made with the air compressor. Three cocks or valves placed on the upper floor permit all this manœuvring. The pressure gauge is watched as soon as connections are made. When the dial points to zero, it indicates that the air escapes through the bottom valve of the diffusor and that the latter is empty. This operation lasts only 30 seconds for a diffusor of over 80 hectoliters capacity. The valves are again closed so that the diffusor may be filled with fresh slices.

The emptying pipe of each diffusor connects with the general compression pipe, which carries the exhausted cossettes into a receiving tank of a capacity equal to that of one diffusor. The residuum is carried by gentle pressure to the cossette presses (Fig. 132). By this process 2700 kilos of cossettes are raised 13.2 meters under 2½ atmospheres pressure in 25 seconds. The advantages of the process include doing away with the man in charge of emptying channels, elevator, etc., excessive cleanliness, and the reduction of the cost of repairing to a minimum. As there is no necessity of receiving the residuum in a lower cemented cistern, the foundation for the entire battery need be only of the most simple arrangement, merely strong enough to resist the vertical downward pressure. The cossettes are more thoroughly and regularly exhausted as the juice is drawn off from the centre, and it is possible to maintain a high temperature in all the diffusors. The use of hot water for diffusion is not new, but seldom exceeds 35° C. and 40° C. in the last diffusor. The supposition was

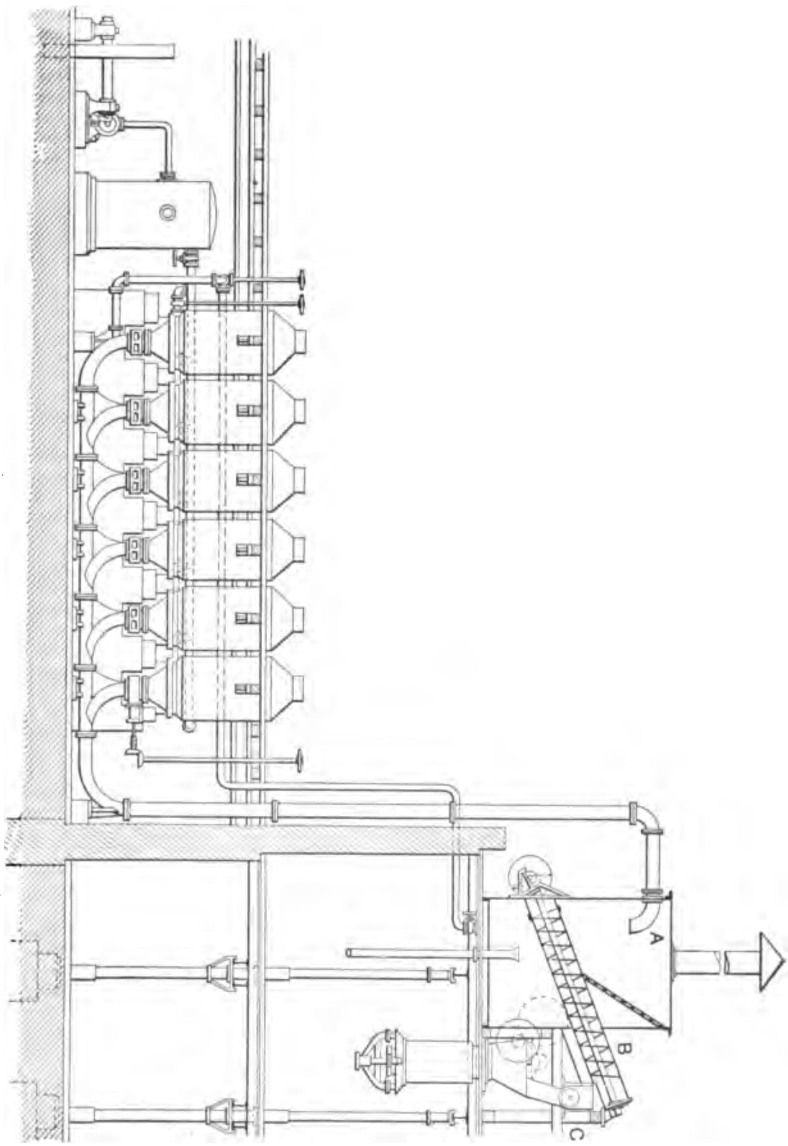


FIG. 132.—General Arrangement of the PFEIFFER Automatic Diffusor-emptying Combination.

that the residuum, if excessively heated, would have no keeping powers during siloing; numerous recent experiments, however, prove that the hypothesis was not justified.*

**Starting of a diffusion battery.**—To start a diffusion battery satisfactorily, certain essential conditions must be attained. The maximum temperature should be established as soon as possible, and hot water consequently is much better than cold. In starting the battery three diffusors should be filled with hot water which may be obtained by reheating the water, passing from one diffusor to another in the calorizators or by taking it from one of the stations of manufacture (water of condensation and evaporation). Before the heating begins the battery man should see that all the valves and steam cocks are in their correct positions.

The temperature of the water should not be higher than 70° C., otherwise the fresh cossettes will be overheated at the start and cause a faulty circulation. Four to five diffusors are successively mashed with hot water and the juice which circulates between them is kept at the desired temperature. Then only is the first juice drawn off into the measurer, and thus from two diffusors the contents of one-half the measuring receptacles may be run off. When the requisite number of diffusors is in full activity, that is to say, filled with cossettes and running with regularity, the pre-

* Cold siloed cossettes become heated after a time and undergo lactic fermentation which puts them in a condition to be eaten with avidity by cattle. This fermentation is much more rapid with the hot siloed residuum than with the cold, as it need not undergo a preliminary heating. When the cold siloing has been carelessly done there are dangers of acetic acid fermentation, which need never be dreaded with hot siloed cossettes. Beet residuum if exposed for a considerable period to the air will rot, and these organic changes are much more to be dreaded with hot than with cold cossettes, but may be entirely overcome by a suitable dirt covering over the outer surface of the silo. It is very important for the good keeping of the product, that the tissue structure of the beet be in no way modified by an excessive temperature during diffusion. For ordinary working of the diffusion battery, the beet slices contained in the diffusors come successively in contact with juices of a gradually decreasing density and temperature, until, when reaching the last diffusor of the series, they are entirely exhausted of their sugar by the cold water contained therein.

The tables herewith show that, even at 62° C., when certain albuminoids begin to coagulate, there need be no apprehension of their finding their way either into the juices or into the sweet-water waste. By cold methods of working, on the other hand, these advantages do not exist. In the first series of experiments the diffusors were all worked at the same temperature,

arranged standard temperature should be maintained. The last diffusors should be separated and emptied in order. The cossettes of the first diffusor are usually well exhausted of their sugar, but the juice first drawn off is necessarily very dilute, and only after filling

viz., 62° C.; the second series at 75° C., and in the third the temperature was first raised to 81° C., and then reduced to that of water heat.

EXPERIMENTS PERFORMED AT VARYING TEMPERATURES.
DETERMINATIONS.

| | I. 62°. | II. 75°. | III. 81°. |
|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. |
| The waste water from presses contained in protein substances................ | 0.073 | 0.060 | 0.065 |

COMPOSITION OF DRIED COSSETTES, DEDUCTION BEING ALLOWED FOR MOISTURE, SAND, AND CLAY.

| | I. | II. | III. |
|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. |
| Raw fat............................ | 1.48 | 1.71 | 1.17 |
| Salts................................ | 4.45 | 4.49 | 4.62 |
| Raw protein......................... | 8.90 | 9.21 | 8.65 |
| Raw fiber (cellulose).................. | 19.03 | 18.75 | 18.15 |
| Non-nitrogeneous extractive substances.. | 66.14 | 65.84 | 67.41 |
| | 100.00 | 100.00 | 100.00 |
| Diffusion juices: | | | |
| Brix............................ | 14.4° | 14.5° | 13.35° |
| Sugar........................... | 12.64% | 12.66% | 11.65% |
| Purity.......................... | 87.80 | 87.20 | 87.30 |
| Massecuite: | | | |
| Sugar........................... | 87.90% | 87.50% | 87.10% |
| Water........................... | 5.80 | 5.47 | 6.50 |
| Ash............................. | 2.60 | 3.04 | 2.78 |
| Organic non-sugars............... | 3.70 | 3.99 | 3.62 |

The cossettes of experiments II contain a higher percentage of albuminoids than the others. For this reason the waste water of II contains less, due to the fact that the temperature being higher from the start the albuminoids were more rapidly coagulated. From a German commercial standpoint, the residuum in question has a nutritive value of 4.99 marks, while the others were worth 4.95 marks and 4.97 marks, respectively, per 50 kilos.

The exhausted cossettes are pressed at 62° C., and as the hot residuum is more readily pressed than the cold, the final product contains more dry matter, the average during the last campaign having varied between 14.8 and 15.1

the measurer six or seven times is the desired concentration obtained. To overcome this difficulty it may be found desirable to draw off less juice from the first diffusors. A diffusion battery should be started gradually, otherwise there is always danger of an excessive softening of the cossettes, which often occurs.

**Stoppage of the battery.**—Whenever there is some special reason for stopping the battery, it becomes necessary to close all the steam valves of the various calorizators. With good healthy beets a stoppage for 12 hours offers no specially objectionable features, provided the temperatures are lowered in the diffusors. Many sugar factories are not run on Sunday, and a rest is permissible if after having drawn off the very concentrated juice the work recommences at night with very diluted juices. This mode of working, however, is not desirable, as certain changes always take place in the composition of the juices, and in point of economy nothing is gained, there being comparatively little saving in fuel, as when starting again almost all the exhaust steam escapes without being utilized. Some experts recommend that the battery be entirely emptied, as thoroughly cleaned as time permits, and the working begun again with fresh juices. Whenever a stoppage of a few hours seems necessary, it is better, if possible, to work slowly rather than to stop entirely. It is always desirable during the battery's inactivity to keep up the temperature so as to avoid any possible danger of fermentation, and this necessitates some circulation of the juice, otherwise, as mentioned before, the cossettes would simply be cooked.

**Emptying the battery.**—No special rule can be given as to the best mode of emptying a diffusion battery, as it differs in the various factories. CLAASSEN says that the emptying of the battery should be accomplished by separating and emptying one diffusor after another, drawing off from each at certain intervals sufficient juice to fill two measurers. At the end there are only four diffusors in connection, and the drawing off continues until the juice retains only 0.3 to 0.5 per cent of sugar. MALANDER seems to favor the following mode for emptying the battery: A diffusor is thrown out

per cent, as compared with 13.4 per cent of the previous year. As the residuum is sent hot to the dryer there follows an economy of fuel to the extent of 42 kilos of coal per 100 kilos of dry cossettes obtained. Under these circumstances the daily capacity of the dryer is increased. The initial heating of the residuum is indispensable in eliminating the inconveniences hitherto existing. This is accomplished by preliminary heating during diffusion, the product remaining hot until it reaches the presses, as all apparatus are closed.

after the juice is drawn from the leading compartment of the series; then another is taken off after two more are drawn off and sent to the measuring tank, and this method is continued, always drawing off once or twice before another diffusor at the other end becomes inactive. For short batteries, experience shows that it is necessary to draw off at least twice before the last four or five diffusors are successively thrown out, and towards the end the drawing off continues until the juices contain about 0.5 per cent of sugar. With inferior beets the limit should not be less than 0.5 to 0.75 per cent. If this percentage is rather above the normal the additional loss is of very little importance compared with the advantages of keeping the quality of the juice up to the desired standard. Under all circumstances the juices from the battery toward the end of the operation have a composition that is always less than that of ordinary juice. Their purity falls considerably, and this is not rectified even by defecation, as they contain organic non-sugar, which forms calcic salts during the defecation, and may make the subsequent work very difficult, especially the last graining in pan at the end of the week.

**Special modes of working.**—In the report of the French Sugar Manufacturers' Syndicate the methods of working are divided into the slow and the rapid modes, the former working at a comparatively low temperature. The installations and the working of the plants examined by the expert may be considered first as consisting of a unique battery made up of twelve, fourteen, and sixteen diffusors. Cold water is circulated through the last diffusor of the series and the combination is such that the temperature gradually rises from one diffusor to the other. At about two-thirds of the length of the battery three to four diffusors may be found that have the maximum temperature. At the beginning of the series are the fresh cossettes where the warmer juice has its temperature lowered, and the juice drawn off is at 28° to 32°, while at the centre it reaches 75° to 80° C. From six to eight diffusions are made per hour and an average of 53 kilos of cossettes are allowed per hectoliter of juice contained by the diffusor. Consequently with a battery of twelve diffusors of 25 hectoliters it becomes possible to handle during 24 hours $25\times 53\times 7\times 24$ or 220 tons, or 8800 kilos or 9 tons per hectoliter of the practical capacity of the diffusor. When the battery consists of fourteen diffusors its capacity evidently increases, but the cossettes must be submitted to the same degree of exhaustion. All things being equal, it is necessary that the period the water and the

cossettes are in contact shall remain the same, about 85 to 90 minutes. Therefore, twelve diffusions must be completed in 85 minutes or 8.4 per hour, or for a day of 12 hours $25\times53\times8.4=$ 270 tons or 10.6 tons per hectoliter of the practical capacity of the diffusor. With a battery of sixteen diffusors working under the same conditions it would be possible to work 320 tons a day, supposing that there are ten diffusors emptied and filled each hour. It is conlcuded that if batteries of twelve, fourteen, and sixteen diffusors be compared their efficiency is proportioned to the number of diffusors in activity, provided, however, that the period of contact remains the same in each case. This law remains constant whatever be the capacity of the diffusors.

In the hot, rapid types the batteries may be divided into sub-batteries of seven, eight, nine, and eleven diffusors, arranged so as to receive the cossettes under the best possible conditions, and generally arranged in two straight lines or in a circle. They are alternately worked by the same gang of men, each sub-battery having only one diffusor that is not working. As a general thing the last diffusor receives hot water at 35° to 50° C., and the heating is arranged in such a way as to reach the desired maximum in the least possible time. The first diffusors are heated and the juice drawn off is hot. As each sub-battery is shorter it offers less resistance and it is possible to add 56 kilos of cossettes per hectoliter of practical capacity of the diffusor. The cossettes remain in contact with the circulating juice from 60 to 70 minutes. With two sub-batteries of seven diffusors and twelve diffusors being emptied each hour, the daily working will be

$$12\times56\times25\times24=400.2 \text{ tons,}$$

or 17.5 tons per hectoliter of practical capacity. The weight of beets that may be handled with sub-batteries of 7, 8, and 9 is proportional to the number of diffusors in activity, provided the manner of working remains the same. The factories visited in France by the expert of the syndicate had in one case two sub-batteries of seven diffusors of 33 hectoliters and handled 600 tons of beets per diem; 117 liters were drawn off and the cossettes contained only 0.33 per cent of sugar. The other plant had two sub-batteries and seven diffusors of 30 hectoliters. Each one handled 250 tons per diem, and drew off 117 liters, the exhausted cossettes containing 0.25 per cent of sugar.

**Working with dirty water.**—In an emergency the battery may be operated by introducing into the end diffusor after the first one has undergone the preliminary stages of mashing, under which conditions the total volume of decanted water used is somewhat less than would be necessary to mash up the leading diffusor; consequently there need be no apprehension lest this water reach the bottom of the end-diffusor and be introduced into the following one. Before resorting to this expedient, however, the clean water should be economized in every possible way. The dirty water, or rather the residuum water from the diffusion battery, may be employed over and over again for this purpose, after having rested long enough to be separated from the suspended impurities. As soon as the mashing is finished the last diffusor is thrown out and emptied of the dirty water. The drawing off is operated while the clean-water valve is open upon the new end diffusor. Some maintain that the decanted water may be advantageously used when the diffusor is thrown out during the drawing off instead of during the mashing, but further experience is needed to decide this point. The volume of juice drawn off with waste water is then only about 40 per cent of the diffusor's capacity. The criticism made of this method is that the residuary water, which is thus repeatedly used, becomes overcharged with micro-organisms, and if certain precautions for cleansing are not taken fermentation sets in and may cause inferior extraction for the rest of the campaign. PFEIFFER, however, claims that through the use of his closed apparatus these dangers are obviated.

**Compressed air** yields far better results than decanted water, although the method of working is the same. If air should find its way into one of the next diffusors it would stop the circulation of the juice in the battery. The compressed-air plant necessitates an additional compressing arrangement and an air reservoir. The air is at the same pressure as water would have been in the battery, and when this is exceeded the air escapes through a well-arranged safety valve.

A number of modifications of the ordinary diffusion methods have been proposed, but no satisfactory results have been obtained with them. Attempts have been made to do away with many of the valves used in the existing types of diffusion batteries, and also to effect the diffusion in one diffusor; but these have not been successful, owing to the impossibility of preventing the mixing of juices of different densities. Under such circumstances the

exhaustion of sugar from the beet slices is never satisfactory, although only very dilute juices are drawn off.

**Divided batteries.**—TOURKIEWICZ in Russia who had exceptional difficulties to contend with in the way of poor beets adopted the following plan: The juice was alternately drawn off from each of the two sections of a divided battery, but though the period of diffusion was the same per 100 kilos of beets, the juice remained twice as long in the diffusors, because in one continuous battery each filling of a diffusor corresponded to the drawing off of the juice from one and the mashing in another, while in two batteries (consisting of a single battery cut in two) during the filling of the diffusor of one series, the other remained stationary during mashing, the drawing off from the latter being effected when the filling was done. There are consequently, during the same interval of time, two displacements with a continuous battery and only one with a divided battery. However, a very simple calculation shows that a single battery of fourteen diffusors and two batteries of seven diffusors, each working alternately, should give in the end the same result. It is essential that the same number of diffusors should work in the two cases. As the divided battery necessitates considerable additional work and is complicated, it should be adopted only in very exceptional cases where very poor beets must be handled that might clog the passage of the juice when there is a large and interrupted series of diffusors. At the Sainte Marie Kerque beet-sugar factory, LEGIER says that the diffusion battery in two sections gives 110 liters of juice per 100 kilos of beets sliced, and consists of eighteen diffusors of 38 hectoliters. The division of the battery is obtained in a very clever manner with a view to obviating the necessity of a semi-circular revolution of the beet-slice hopper when changing the diffusors. The diffusors 1, 3, 5 . . . 17 communicate with each other and form one battery, and the numbers 2, 4, 6 . . . 18 form the other battery. The cycle of the battery consists in reality of fourteen diffusors, besides four placed in the interior of the circle. But the temperatures of the diffusors of one battery are the same as those of the others; as a consequence, the working of the two batteries is exactly the same as that of an 18-diffusor combination. Under these circumstances the control is easy and the cost is considerably reduced.

**Continuous diffusion.**—The only continuous diffusion apparatus in actual use for any length of time was that of CHARLES and PERRET (Fig. 133). It consists of a large closed cylinder with

double sides, the sheet-iron interior being perforated and containing a slowly revolving spiral *E*, 8 meters long and 1 meter in diameter. The beet slices are introduced through the hopper *A*, and at the other extremity the water is fed to the apparatus at 70° C. through *R*. The cossettes consequently travel in an opposite direction to that of the juice and the diffusion water, and upon reaching *Z* are exhausted of their sugar. From there they are taken by a moving band to the cossette presses. As the circulating liquor would have a tendency to pass through the perforations into the outer cylinder, this difficulty is overcome by having as many sheet iron annular divisions as there are spires to the helix. These rings force the juice to pass through the mass of cossettes and to progress towards the other extremity of the apparatus. This appliance had many objection-

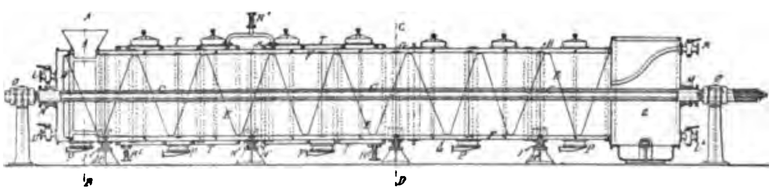

FIG. 133.—CHARLES and PERRET Continuous Battery.

able features,* among which may be mentioned an excessive dilution. Under the most favorable conditions the exhausted cossettes retained 0.5 per cent of sugar.†

Among the more recent continuous processes may be mentioned the BERTRAM‡ diffusion (Fig. 134). The combination is most simple, and if practicable it should be very economical. The beets fall into the slicers *a*, and subsequently into a hopper beneath; by the rotation of an endless screw *b* they enter the diffusor *o*; here they come in contact with the circulating juice; on reaching the bottom they are carried horizontally, the arms *k* bringing the semi-exhausted cossettes very thoroughly in contact with the juice during their rotation. The screw *m* forces the mass through a conical cylinder, then into a horizontal cylinder *p*, a slanting endless screw *r* carries the pulp forward. Much of the water is pressed out just as it would be in a KLUSEMANN press and is still further separated during its upward journey before being thrown out. It is important to note that in the diffusor *o*

* S. I., **15**, 107, 1880. † S. I., **16**, 659, 1880. ‡ Z., **48**, 937, 1898.

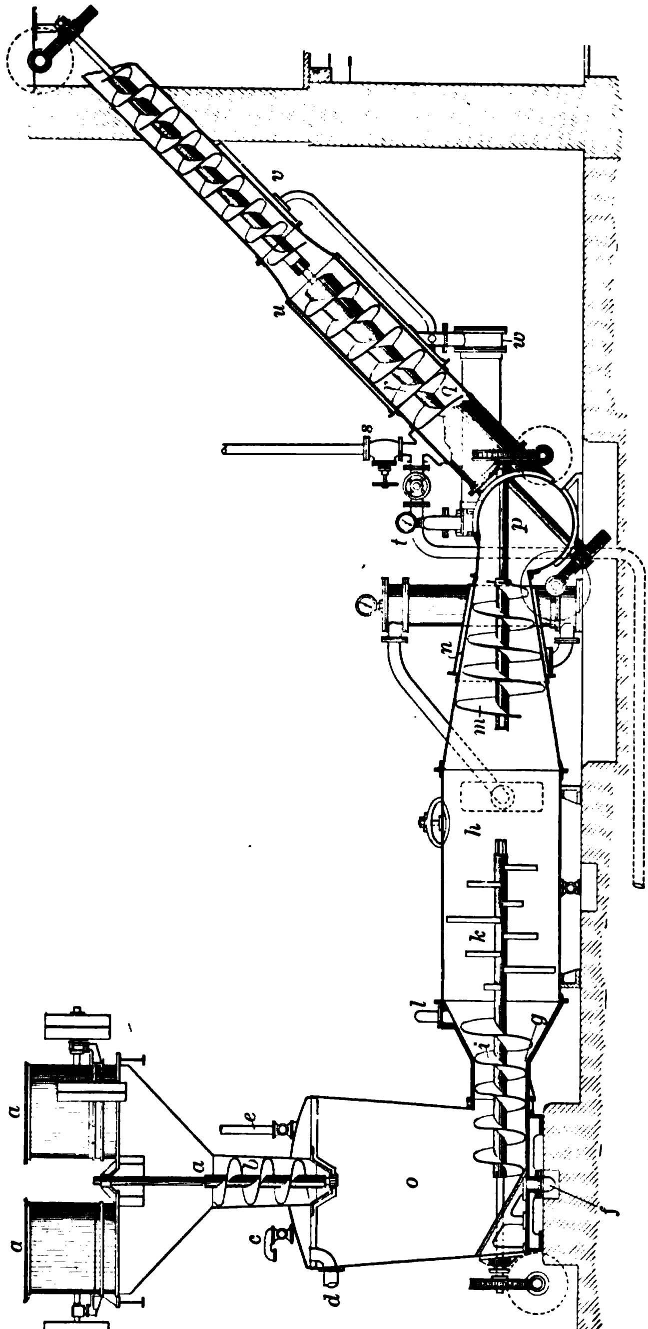

FIG. 134.—BERTRAM Continuous-diffusion Battery.

a vaccuum of 0.13 to 0.16 atm. is essential for the proper working of the appliance. The juice is drawn upwards with the water that enters at *s*. During its passage through the appliance there are several filtering cloths such as *n*, etc.; here the juice separated escapes and flows into reheaters, and re-enters the apparatus; finally, the juice escapes from the diffusor at *d*.

Continuous diffusion of the KESSLER * type consists of a tube, bent in V shape, of a length about equal to six ordinary diffusors and of about the same diameter as a diffusor. Two spirals are combined for filling and emptying the diffusor of its cossettes, which also form a closing with a cone, very like the combination used in cossette presses, through which the cossettes, but not the juice, may pass. Beneath these compressing cones the sides of the pipes are perforated, on the one hand for allowing the hot water of the diffusor to enter, and on the other for the exit of the diffusion juices. From above the tightening cone, on the sides where the cossettes enter, the juice extracted is forced beneath the cone where it is reheated and rises along the sides of the screw, heats the cossettes with which it comes in contact and runs off from the top of the apparatus, passing through perforated sheet iron into the pulp separator and thence into the measuring receptacle. Between the place where the water enters and the tightening screw on the emptying side the apparatus is also perforated, and the partially pressed cossettes yield the water they contain. After leaving the apparatus the cossettes are again put through the regular presses. The sweet water obtained by the first pressing is comparatively pure and may be returned to the diffusors. Under these conditions the residuum cossette pressing need not be pushed to the usual limits.

**Heating the head of battery.**—In order to coagulate the albuminoids already in the cells, so that they can no longer form part of the juice, it has been proposed to reheat the juices by means of injected steam or to introduce very hot juices at the temperature at which the albumen coagulates in the diffusors upon fresh beet slices. It is, however, doubtful whether this mode has any practical utility, as the albumin that may be thus coagulated has a very limited influence on the subsequent working of the juices. This plan is very difficult to put into practice, because the reheating with steam dilutes the juice, and the cossettes thus

* D. Z. I., 28, 22 and 61, 1903.

heated have a paste-like texture and offer considerable obstruction to the general circulation of the juice in the battery.

The HENZEL * mode which met with very indifferent success, consisted in injecting hot air at 80° C. into the diffusors.

One general defect frequently pointed out in the ordinary diffusion battery is that the juice entering the diffusor last filled is not sufficiently hot to give the best results, the juice drawn off being only warm. Upon general principles a diffusor is mashed from bottom to top, and when drawn off the juice comes from top to bottom. Evidently the juice at the bottom has taken no part in the diffusion. To reheat the juice in this compartment to a maximum temperature NAUDET proposed to force it to circulate not only through its own calorizator, but also through a reheater independent of the battery, this circulation to be continued until the desired temperature is reached. During this period the second diffusor of the series is drawn off. The cir-

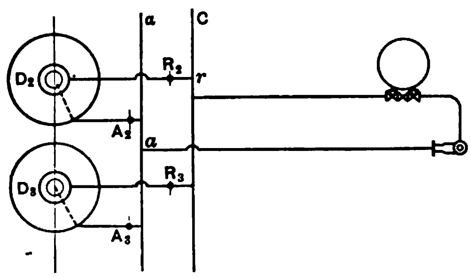


FIG. 135.—Diagram of Arrangement of NAUDET's Method.

culation is effected by a centrifugal pump. It is recommended not to use steam at a temperature higher than 5° C. above that which the juice should ultimately have. A small pipe connects the diffusor being heated with a receiver so as to allow for the expansion of the liquid. It is claimed that under these circumstances the heating of the juice is very economical. There follows a coagulation of the albuminoids in the fresh cossettes, and in consequence a higher purity of the juice, combined with an increased efficiency of the battery.†

Practically the NAUDET (Fig. 135) process is conducted in the following manner: The diffusors $D_2$ and $D_3$ have the standard piping attachments which are not shown in the diagram herewith,

* B. As., **10**, 579, 1893. † D. Z. I., **25**, 1766, 1900.

and also two special pipes, one leading to and the other from the reheater. The mashing of $D_3$ being completed, the valves are manipulated to draw off not $D_3$, but $D_2$. The valves $A_3$ and $R_3$ are opened, the pump is set working, the juice passes through the reheater and the beet slices, and after the second circulation has a temperature of nearly 80° C. This centrifugal pump should be sufficiently powerful to force several circulations during the drawing off and mashing, as the mashing of the diffusor $D_4$ is also accomplished with the juice from $D_2$ by closing $S$ and opening $J_4$ (see Fig. 123). When the mashing is finished $J_4$ is closed to isolate $D_4$ and to force it also to circulate. $J_2$ is closed, $c_2$, $J_3$, and $S$ are opened and the juice from $D_3$ is sent to the measurer. The working of this process varies very much with local conditions.

This mode continues to yield most satisfactory results. A factory in which it has been introduced had a daily capacity of 650 to 700 tons, and with two batteries of eleven diffusors each the forced circulation brings the capacity up to 785 tons per 24 hours. With beets testing 16 per cent sugar and a purity coefficient of 85.7, the method gave juices in the battery containing 15.25 per cent of sugar and a purity of 87.5, which means 1.8 purity higher than the original juice. There remains 0.28 to 0.35 per cent sugar in the residuum cossettes from 100 kilos of beets, and there were drawn off 103 to 104 liters of juice, while by the previous mode the same percentage of sugar remained in the cossettes, but the volume of juice per 100 kilos of beets was 115 to 120 liters, which means very much more juice to evaporate and consequently a greater consumption of fuel, to attain the same results. At the Nassandres (France) sugar factory an increase of from 85 to 110 tons of beets are being sliced per diem since the NAUDET apparatus has been introduced. The resulting juices had a purity of 87.52, and were epurated with 2.5 kilos of lime per hectoliter of juice. After the second carbonation the purity was 91.5. Practical tests were made in several factories, and the results obtained were always most encouraging, and thoroughly endorse the practical value of this innovation in the working of a diffusion battery.

JELINEK * has obtained some excellent results by directly heating at 50° C. the fresh diffusion cossettes in the first diffusor and mixing with juice nearly at the boiling point taken from a diffusor

* D. Z. I., **26**, 635, 1901.

previously mashed. To prevent the bad effects of excessive heating the juice is kept at 69° C. in the diffusor. By old modes of working it was impossible to keep such a general low temperature in the battery without causing sugar losses or retarding the working. The high temperature favored the salt diffusion. The beet juice used for mashing seldom had a temperature higher than 36° C. By the new mode of working the juice is heated in a special receptacle up to 95° to 97.5° C., and in this hot condition it is subsequently used in the diffusor being mashed. The concentrated juice from the recently mashed diffusor is sent to the measurer and from there to the carbonatation tanks. The next diffusor is filled with fresh beet slices and mashed with hot juice from the reservoir, during which period the juices of the preceding diffusor are drawn off and are run into a reservoir where they are heated and subsequently used for mashing in another diffusor. The newly mashed diffusor is then connected with the battery and its first juices are run into the carbonatation tanks, as explained in the foregoing, etc. The satisfactory working of this method demands two reheating reservoirs, so as to mash with hot juice in one diffusor while the other diffusor is being filled. It is claimed that the diffusion would thus be more rapid and the cossettes more thoroughly exhausted.

Upon taking into consideration the NAUDET* experiments, in which the work is conducted under much the same principles as those just described, it was concluded that it is not possible to heat the cossettes excessively by the JELINEK method. Even in mashing at 80° C. the juice then drawn off to be sent to the measurer would be at an average temperature of not more than 35° to 40° C. in the battery. It is pointed out that it would be difficult to use juice as hot as JELINEK proposed as the top layer of cossettes would simply be cooked and the circulation of the battery would come to a standstill. The MELICHAR mode is apparently only copy of the NAUDET mode, although CERNY claims that it was in existence in Austria in 1895, that is to say a long time before the NAUDET process. MELICHAR† mashes the diffusor of a battery with the juices from the compartment previously filled; the juice that continues to arrive is sent to the measuring tank, and during this interval communication is made with a pump which forces the juice through the so-called circulator and a tubular reheater,

* B. As., 18, 569, 1901. † B. Z., 25, 449, 1900–1901.

and the juice thus heated returns to the same diffusor from which it was drawn and then passes into the next diffusor to be filled. The juice drawn off has a temperature of 75° to 85° C. It is claimed that by this system of heating there follows a fuel economy of 0.9 per cent. The diffusion battery need consist of comparatively few compartments.

The FOELSCHE * process also resembles the NAUDET mode, but instead of drawing off the juice from a diffusor recently mashed with fresh beet cossettes, FOELSCHE forces it to circulate through the preceding diffusor, so that the juice drawn off shall be hotter and the cossettes thereby also better heated, attaining as soon as possible the temperature of 80° C. To accomplish this there is placed on the pipe between the diffusors a valve that permits the battery to be divided. Hot juices are drawn off from the third diffusor and sent to the measurer. After this drawing off another mashing follows, as is customary in the regular methods of working, and the operations are successively repeated.

BAERMANN † combines with his mode of working the diffusion battery a circulation through the cossettes in the diffusors of a series of diffusion juices containing decreasing sugar percentages. After the first of these solutions has passed through the cossettes of the first diffusor and a juice reheater, and the cossettes are sufficiently hot, the second solution is run through the same cossettes in the same diffusors and a certain volume of juice is drawn off and sent to the carbonatation tank. The other diffusors of the battery are worked in the same way, a volume of liquor about equal to that removed in the first section being drawn off so as to obtain a systematic working of the battery. About ten solutions are used. When the weakest solution has been run through the last diffusor of the series the diffusion proper is completed. The exhausted cossettes are subsequently ground and sent through pumps to the pulp presses. The sweet water running off is used to replace that which is removed from the battery and sent to the last juice receptacle.

Upon general principles very long batteries are not desirable. However, it is difficult to bring about the desired diffusion unless the circulating liquid comes in contact with the cossettes for a considerable period of time. Evidently when this is pushed to excess a large quantity of salts is always dissolved as well as sugar, and the juices become more and more impure. STEFFEN claims

* D. Z. I., 28, 337, 1903. † Z., 51, 951, 1901.

that in all existing diffusion batteries the beet slices are very much more rapidly diffused in the upper portion of the diffusors than they are on the lower levels, such being the case the duration of diffusion is considerably and unnecessarily lengthened, and, furthermore, there is a difference in temperature between the upper and lower strata of the beet slices. In the very lowest layers there is always considerable organic transformation, etc., going on which causes great impurity of the resulting beet juices. BAERMANN (STEFFEN) * proposes to stop the extraction when the cossettes still retain 2 per cent of sugar. The juices thus drawn off are submitted to a regular epuration by lime, carbonatation, etc., and the ultimate purity is higher than it would otherwise have been. The exhaustion up to a 2 per cent sugar limit is rapidly accomplished, but the continuation of maceration in the new apparatus proposed by STEFFEN demands more time and presents certain difficulties. The cossettes fill a long iron cylinder closed at the bottom by the disk of a machine that grinds the beet slices. These are pumped and forced through presses and give a final residuum containing less than 2 per cent of sugar or less than 0.5 per cent of the total sugar contained in the original beet. The macerator used is very high and of a very much smaller diameter than the average diffusor. About one-third of the distance from the top the juice is collected from each diffusor, pumped through a reheater and allowed to flow back into the compartment on top of the fresh beet slices, subsequently leaving the apparatus through an upper opening. The slices when nearly at the bottom of the macerator are thoroughly mixed with the juice by a rotating appliance. After the product has been reduced to a pulp-like condition it flows into a pipe and is pumped through a pulp strainer, the juice thus separated running back into the macerator from which it was taken. The operation is continuous. The juice thus forced out is sent to the lower part of the macerator and rises to the normal level, at which spot the iron of the cylinder is perforated so as to allow the liquor to pass into a measuring tank. A portion of this juice can be drawn off with a centrifugal pump from a ring surrounding the perforated portion of the cylinder and is forced through a reheater to be emptied in an almost boiling condition on top of the fresh cossettes of the macerator. Special mixers carry the exhausted cossettes to the grinder where they are reduced to

* D. Z. I., 26, 1922, 1901.

paste. The pipe connecting with the presses has a branch pipe at the lower extremity of the macerator to assure the proper working of the grinder which might clog owing to the fluid consistency of the paste. The portion of the building where this diffusion is conducted has a height of 4 meters.

The new STEFFEN process, which has already been experimented with, is based upon the principle that fresh cossettes are brought in contact with hot juices at 70° to 80° C. and are at once pressed. It is pointed out that the percentage of dry matter in the residuum is increased. The juice goes through a sort of preliminary heating at 95° to 100° C., and is mixed with fresh cossettes in the proportion of about 1:5. As soon as the beet slices have reached the desired temperature they are pressed. It is pointed out that under these circumstances one obtains 70 parts of juice for 100 parts fresh cossettes, and the 30 parts of residuum contain 30 to 35 parts of dry substance. As no water is used, the ultimate juice obtained is more dense and has a higher purity coefficient than is obtained by standard modes of working. After defecation and carbonatation the actual average gain in purity is not more than 2 per cent.

The results realized by this method do not appear to us to offer any special advantage. It is claimed that notwithstanding the high sugar percentage of the residuary cossettes, that the sugar yields are higher than by any of the existing modes of diffusion. STEFFEN maintains that there are very important unknown sugar losses in the battery; this assertion has been refuted by numerous experts.

**General considerations.**—From what has been said in the foregoing, several characteristic modes of working, depending upon local circumstances, may be distinguished. CLAASSEN discussing this question says:

(1) When using long batteries of twelve to fourteen diffusors, of which ten to twelve are in full activity and of comparatively small capacity (20 to 30 hectoliters), the cossettes should be very fine. The high temperature must be maintained throughout the entire battery even up to the last diffusor by using hot water during diffusion. The operation should be short, about 1 to 1½ hours, while the changing of the diffusors and the circulation of the juice should be very rapid. Under such circumstances the juice drawn off will be satisfactory as to volume and concentration.

(2) When using long batteries, with twelve to fourteen large

diffusors of 50 to 80 hectoliters capacity, the cossettes should not be too fine, but very regular. The temperature in the diffusor leading the series should be high, but in the last diffusor very low, the water of diffusion being warm. The operation should last from 1½ to 1¾ hours. The circulation of the juice is less rapid and the number of diffusors emptied in a given time smaller than in the case first mentioned.

(3) When running in a short battery with six to eight large diffusors the cossettes should be the same as in the second case, the temperature in all the diffusors as high as possible, the water of diffusion hot, and the duration of the operation shorter than in the second case, about 1¼ to 1½ hours. The changing of the diffusors is, however, less frequent, the circulation of the juice slower, and the volume of juice drawn off greater.

When handling a diffusion battery already existing in a factory it is desirable to decide which one of the three methods just mentioned will give the maximum production, combining the greatest concentration of juice with a superior exhaustion of the cossettes.

**Testing the working of a battery.**—A reliable and rapid method for determining the conditions existing in a battery has long been needed. The microscope might be used, but is not easy to handle in rapid laboratory work during a sugar campaign. The following appears to be a very simple way of ascertaining with considerable accuracy the desired information as to the temperature in the battery. If a handful of refuse pulp pressed between the fingers offers a certain amount of resistance to the pressure, it is concluded that the temperature in the battery has not been sufficiently high. If the temperature has been what it should be the mass is reduced in volume by a slight pressure, retaining at the same time a certain elasticity in all its parts. On the other hand, if the pulp becomes pasty under hand pressure, overheating has certainly taken place, which causes an increased percentage of organic salts in the juice, and these, when combined with lime during carbonatation, are very difficult to eliminate in all subsequent operations.

To make sure that the mode of working is all it should be it is best to adopt a special mode of sugar estimation, the execution of which, however, demands considerable trouble and work and, therefore, cannot be generally adopted. This method consists in taking a sample of juice simultaneously from each diffusor of the battery and examining it for sugar content and purity. These data show the increased sugar percentage in each diffusor, and if

combined in a system of co-ordinates, so arranged that the abscissas correspond to the number of diffusors and the ordinates to the increase in sugar percentage, a curve is obtained which, when working according to rational rules, should have a determined shape. If, on the contrary, the working of the diffusion battery is faulty the curve thus traced will be very irregular, the exhaustion of the cossettes in the different diffusors will not be satisfactory and the total production of the battery will consequently not attain the desired standard of economical working.

This method of testing the working of a battery collectively and of each diffusor separately was proposed by BATTUT.* The first diagram (Fig. 136) may be considered a normal curve for the residuum cossette exhaustion of a battery consisting of seven diffusors. The curves obtained in practice are very different from this theoretical standard if the heating has been neglected. The influence of the temperature is self-evident in the diagrams. The full black line shows the augmentation of concentration of the juice and

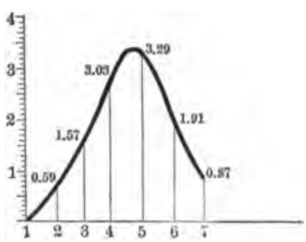


FIG. 136.

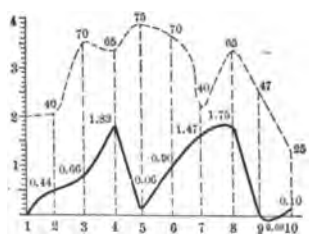

FIG. 137.

the dotted lines give the temperatures. Whenever there is an irregularity of temperature there follows an irregularity in the phenomena of diffusion. Fig. 137 illustrates to a very poor exhaustion, although there is a considerable increase of sugar percentage between certain diffusors. Fig. 138 shows a much more regular working and a considerable increase in sugar percentage between the seventh and eighth diffusors, and without doubt the cossettes in this case were well exhausted of their sugar. In Fig. 139 the increase in sugar percentage of the juice is still more regular, agreeing with the exceptional regularity of the temperatures. The increased sugar percentage between each diffusor is, however,

* S. I., **27**, 414, 1886.

very slight, which is explained by the fact that the beet slices in this case were too large. With only a slight variation in the saccharine percentage the residuum cossettes retain considerable sugar, as might be expected. In Fig. 140 a regular and very satisfactory working is portrayed. The exhausted cossettes contained 0.33 per cent of sugar. BATTUT concludes from this graphic

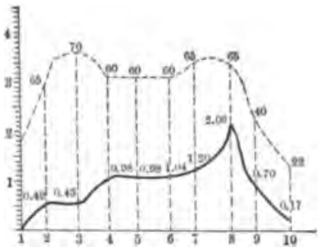

FIG. 138.

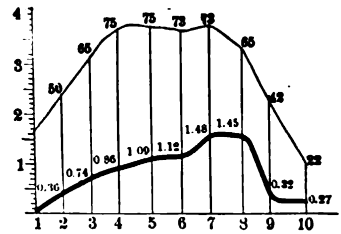


FIG. 139.

representation that the maximum exhaustion takes place at 65° C., and not at from 70° to 75° C., as is generally supposed. The objection to the conclusion is that the albumen would not be coagulated, and hence higher temperatures are desirable in order to obtain purer juices. The purity coefficients were also noted in these tests, but they show such variations that no conclusions could be drawn. On the other hand, FOGELBERG * repeated these experiments and obtained a very regular diagram of purity, comparatively high in the first 4 or 5 diffusors of the series, but falling rapidly in those that follow, especially upon reaching the last. In the first of these experiments the variations of purity were from 88 to 50 and in the second from 87 to 34.

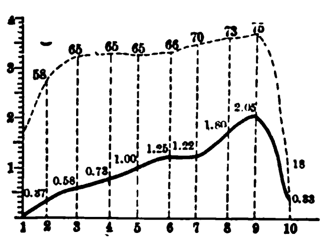


FIG. 140

Since the diagram idea was suggested, SILLMAN † has proposed that it be applied to the working of the battery under average conditions, for the deduction of the most desirable changes to be made for reheating during diffusion. His diagram is obtained by the analysis of the juice of the diffusors in full activity. Allowance must be made for their temperature, but instead of

* C., 6, 734, 1898. † D. Z. I., 27, 1282, 1902.

taking all the samples at the same time it is proposed that the same juice be carefully watched during its passage through the entire battery. The juices during their traject cover a distance greater than the extent of the battery proper, for the reason that new diffusors with fresh cossettes are continually being added. Under these circumstances the temperature curve is entirely different from that of BATTUT, and with a large number of heated diffusors the central portion of the diagram is very nearly a straight line. The density of the juice increases mainly at the head of the battery, and it is there where the purity decreases the most, due to the fact that fresh beet slices have many broken cells which are emptied by washing independent of diffusion. Once the diagrams are in hand the efforts should be concentrated upon raising the efficiency of the battery by increasing the temperature in most of the diffusors with hot water and diluting, within reasonable limits, the juice drawn off. All these rules necessarily vary with the local conditions. CLAASSEN says that no rational, practical results can be obtained by comparing work done on a large scale with the cold or hot digestion of laboratory analysis and the objection is still greater if the juice is obtained by pressing. The best method for ascertaining the working capacity of a battery is by comparative experiments with two batteries handling the same beets, but this is very expensive if carried out on a large scale, and, therefore, the data obtained with small experimental batteries must be depended upon and the work regulated accordingly. The remaining points demanding attention are the thorough exhaustion of the sugar from the beet slices and the obtaining of thick juices. It is the duty of the technical manager of a beet-sugar factory to determine under what circumstances the diffusion battery will give the best results and to effect an installation that will insure the extraction of the maximum amount of sugar. Numerous phenomena are constantly occurring for which allowance must be made. The battery may be shortened when working at a higher temperature, or inversely it may be lengthened and the work effected more slowly.

GOLLER * points out that the rapidity with which the diffusion is accomplished is proportional to the exposed cossette surface, and on this basis he gives preference to the KOENIGSFELD slicing blades rather than to the ridged type. Evidently the finer the cossettes

* Oe.-U. Z., 30, 714, 1901.

are the shorter will be the duration of the diffusion, the efficiency of the battery is increased and the juices are more concentrated, which economizes fuel and labor. On this question CLAASSEN says: "If it were possible to use in a diffusion battery cossettes of a highly polished surface and no thicker than a thread it would be an ideal condition, for the entire operation would then be ended in a few minutes. Small batteries could be used and very small amounts of the insoluble substances would be dissolved, while the juice could at the same time have considerable concentration. Unfortunately it is not practicably possible to produce cossettes of that kind, and it would be impossible to obtain a circulation of juice through cossettes of such exceptional fineness. Most factories are unable to produce continuously cossettes of a thickness of 2 mm., or even smooth slices of regular shape. The duration of diffusion has consequently to be determined upon the basis of the exhaustion of comparatively thick cossettes. The greater their number the longer is the period needed for their exhaustion. Under these circumstances the finer cossettes in the mass will have not only all their sugar dissolved, but there will also be considerable non-sugar in the solution, while the thicker slices will retain more than the average amount of their substance. As before explained, for a rational diffusion the cossettes should be as fine as possible without paralyzing the circulation of the juice in the battery. One should by every possible means endeavor to reduce the time needed for diffusion without introducing new and abnormal conditions of working, for although the juices obtained by rapid methods are purer this result must not be obtained at the expense of leaving a great amount of sugar in the residuum cossette and diluting the juices." It was to gain time that TURKIEWICZ * proposed the division of the batteries into two sections.

**Temperature of diffusion batteries.**—CLAASSEN says that as regards temperature in the battery the limit is reached when the beet slices begin to soften and pack over each other, thus preventing, or at least retarding, the circulation of the juice. This softening takes place at various temperatures depending upon the condition of the beets. Upon general principles it may be said that thoroughly matured beets which have been properly harvested at the right time will withstand a higher temperature than siloed beets. It is possible that the fertilizer used and the weather during the period of

* Z., **39**, 69, 1889.

growth play important parts. If the beets are in a perfectly healthy condition the maximum temperature in the calorizators may reach 80° to 84° C. without the least danger. It is to be noted that the temperature of the cossettes in the diffusor is lower by several degrees than that indicated on the thermometer connected with the calorizators. Under no circumstances can beet slices withstand a temperature higher than 90° C. Evidently much depends upon the period during which these high temperatures exert their influence, hence by working rapidly, that is by frequent change of the diffusors, it is possible to use higher temperatures than if the juice circulates more slowly. If the beets are not in a perfectly normal state, that is if they are bruised, partly decayed, or frozen, the high temperature method cannot be considered as the cossettes (such beets can not be properly sliced to form what may properly be termed cossettes) are already soft and even at a comparatively low temperature become softer still.

As previously mentioned BATTUT pointed out that the most desirable temperature was about 65° C., but he admitted that there was an urgent necessity of keeping it higher in order to coagulate the albumen in the beet cells. When diffusion was first introduced ROBERT declared that the best results were obtained at 50° C. JUTRZENKA and RABBETHKE * in 1875 recommended that the temperature be kept at 68° in the last diffusor, 63° in the last but one, and 60° in those preceding. On the other hand, BERGREEN declared that 75° to 81° C. was the most desirable for a satisfactory diffusion. HERZFELD's † experiments show that the increase of temperature from 65° to 85° C. does not result in a decrease in purity, as had hitherto been supposed. However, according to VIBRANS‡ a relatively low temperature is sometimes desirable. The juices he obtained were purer at 69° C. than at 82° C. These differences in the assertions of some of the leading authorities are after all very slight. KRUEGER called attention to the fermentation existing in the diffusors at low temperature, due to butyric and other ferments which multiply mainly at temperatures of 38° to 50° C., their activity ceasing only at 75° C. These facts have given rise to the arguments relating to high temperatures which are now in vogue. One of the principal objections to low temperatures is that the working of the battery is entirely too slow.

The temperatures to be used differ with long and short batteries

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* Z., **25**, 696, 1875. † Z., **39**, 346, 1889. ‡ D. Z. I., **19**, 1311, 1894.

varying further with the size of the diffusors. The shorter the battery and the smaller the diffusors the higher should be the temperature. The water of diffusion should then be kept very hot, while with large batteries the temperature should be lowered in the end diffusors; in fact, in such cases only a very few of the diffusors can be maintained at a maximum temperature.

The emptying of diffusors by forcing the juice and cossettes to the pulp press by means of compressed air has previously been described. This method allows the operation of diffusion to be carried on at a very high temperature in the last diffusors of the battery and the result is that the beet slices are most thoroughly exhausted of their sugar.

The PFEIFFER * experiments showed that when working the battery at a high temperature, 82° C., the results in every respect are most satisfactory and, contrary to the general belief, the resulting juices are of a better quality than when the battery is worked at 62° C. The percentage of dry matter in these residuum pulps is higher and the battery may be reduced to nine diffusors.

From this discussion it is evident that the temperature in a diffusion battery has a great influence on the results obtained. The temperature for each diffusor should be determined in advance. When this is neglected the composition of the exhausted cossettes will be extremely variable.

**Importance of the quantity of juice drawn off.**—After the question of temperature no issue is of greater importance in effecting a satisfactory sugar exhaustion than the volume of juice drawn off from the diffusor in relation to the quantity of beets being treated. Experiments have long since demonstrated that thick juices are always purer than those of less concentration, and this fact becomes more and more manifest as the residuary water from the battery decreases in purity. On this account and with a view to fuel economy the volume of juice drawn off should be reduced as much as possible. Evidently the ideal condition would be to extract all the sugar and dilute the juice as little as possible. Some authorities recommend that a small volume be drawn off at a time and that very little water be introduced into the battery. In most factories † the juice drawn off represents a concentration of from three-fourths to eight-tenths that of the natural juice of the beet.

* D. Z. I., 24, 1779, 1899.

† B. As., 9, 97, 1891.

The standard volume of juice to be drawn from a diffusor per 100 kilos of beet slices should be based upon the production and exhaustion desired. It generally varies from 105 to 130 liters for 100 kilos of beets sliced, but many factories are content with drawing off about 100 liters. As the cost of coal is usually excessive the volume of juice should never be more than from 105 to 110 liters. If the beets then are not sufficiently exhausted of their sugar it would be well to make some change in the diffusion battery.

The concentration of the juice at the time of drawing off, other things being equal, increases with the volume and the weight of cossettes in the diffusors. The proportion as a general thing is calculated upon a basis of 1 hectoliter of volume. From this point of view large diffusors have an important advantage over small ones. By the use of special tools the beet slices may be made to settle, and thus it is possible to have in the diffusors from 55 to 60 kilos of cossettes, or even more, per hectoliter capacity, while with the smaller diffusors, especially if when working rapidly there is not time to force the beet slices to settle, frequently only 50 kilos occupy the space of 1 hectoliter. Evidently the nature of the cossettes plays an important rôle during the filling, as when finely cut and fresh they more easily settle over one another than do thick or partly wilted slices.

In the BAUDRY * table is given the quantity of juice to be drawn off per 100 kilos of beets in order to obtain juices that would never have more than 20 per cent dilution. This table shows that there would be needed 158.5 liters per 100 kilos of beets when the diffusor contains only 45 kilos of beet slices and 100.2 liters when the weight is 57 kilos per hectoliter of diffusor capacity.

There are, however, certain circumstances under which it would not be possible to extract most of the sugar from beets by reducing the volume of juice drawn off, as for example, when the beets are exceptionally fibrous and not readily penetrated by the water, or again in case of exceptionally rich beets. The volume then should be increased. In case of an insufficient exhaustion every effort should be made before increasing the volume of juice drawn off to ameliorate the quality of the beet slices, to increase the temperature by a special heating of the last diffusors, or to increase

* S. I., **40**, 731, 1892.

THE BAUDRY TABLE.

| Per Hectoliter Capacity of Diffusor. | | | Quantity of Juice to be Drawn Off. | | |
|---|---|---|---|---|---|
| Weight of Cossettes. | Volume Occupied by Cossettes. | Volume Occupied by Juice. | Theoretical per 100 kilos Cossettes. | Practically with 20 Per Cent Dilution per 100 kilos Cossettes. | Maximum per Hectoliter Capacity of Diffusor. |
| Kilos. | Liters. | Liters. | Liters. | Liters. | Liters. |
| 45 | 42.85 | 57.15 | 127.0 | 158.5 | 71.4 |
| 46 | 43.80 | 56.20 | 122.2 | 152.7 | 70.2 |
| 47 | 44.76 | 55.24 | 117.5 | 147.0 | 69.0 |
| 48 | 45.71 | 54.29 | 113.0 | 141.3 | 67.9 |
| 49 | 46.66 | 53.34 | 108.8 | 136.0 | 66.7 |
| 50 | 47.60 | 52.40 | 104.8 | 131.0 | 65.5 |
| 51 | 48.60 | 51.40 | 100.8 | 126.0 | 64.2 |
| 52 | 49.52 | 50.48 | 97.1 | 121.4 | 63.1 |
| 53 | 50.47 | 49.53 | 93.5 | 116.8 | 61.9 |
| 54 | 51.42 | 48.58 | 90.0 | 112.5 | 60.7 |
| 55 | 52.38 | 47.62 | 86.6 | 108.2 | 59.5 |
| 56 | 53.33 | 46.67 | 83.3 | 104.1 | 58.3 |
| 57 | 54.28 | 45.72 | 80.2 | 100.2 | 57.1 |

These quantities are calculated by the use of the formula

$Q=100-\frac{p\times 100}{d}=$ number of liters per hectoliter to be taken from the diffusor.

$\frac{d}{p}$ is the volume of the cossette: $d=$ density; $p=$ weight per unit capacity of diffusor.

The theoretical volume for 100 kilos of cossettes is

$$Q'=\frac{Q\times 100}{p}=\left(\frac{100-p\times 100}{\frac{d}{p}}\right)100.$$

the volume of cossettes in the diffusors under those conditions that the volume of juice drawn off remains the same and the looked for results are obtained.

**Conclusions regarding results of diffusion based upon the examination of the juice and exhausted cossettes.**—The limit to which the exhaustion of sugar in the cossettes should be carried still remains an open question. There are certain facts, however, which must not be overlooked. If the battery is comparatively small and the weight of beets to be handled large, it would not be rational to attempt an excessive exhaustion with an increased amount of juice, such as would decrease the daily production as the sugar gain would be neutralized or even exceeded by the cost of manufacture. If, on the other hand, the battery is sufficiently large to meet the emergency, it would be a great mistake not to push the exhaustion as far as possible, always keeping the temperature within the necessary limit and allowing for the diffusion such an

interval of time as would lead to the best results. Lest the juices of the last diffusors have a considerably reduced purity and thus decrease the yield it is desirable to draw off always about the same volume of juice.

GROEGER * concludes, after a long series of investigations, that the volume of liquid drawn off from a battery has an important influence upon the purity of the diffusion juices. However, these differences disappear in the *massecuite*, or at least are considerably lessened. The purity coefficient of a *massecuite* does not depend upon the diffusion juices but upon the quality of the beet increasing with its saccharine percentage. It is furthermore maintained that the non-sugar finally extracted is gradually eliminated during the various phases of epuration. The potash thus extracted takes the place of the lime salts in the juice. If the drawing off diminishes the purity of the diffusion juices increases, but the increase is not noticeable in the *massecuite*.

It is undoubtedly a great mistake to base any conclusions as to the perfection or faults of a diffusion battery upon a comparison of the purity of juices obtained from a battery and those produced by a simple pressing of the pulp in the laboratory. It is a well-known fact that the purity of a juice obtained from the same beet in the laboratory varies with the fineness of the sample and the pressure to which it is subjected. Furthermore, the juice of beets that have developed under different conditions may vary greatly in quality and quantity. Consequently the purity of the juice does not always permit of exact conclusions as to its value, for the simple reason that the nature of the non-sugar differs, and one never knows what percentage may be eliminated through defecation and carbonatation. It frequently occurs that a diffusion juice with a low purity quotient will give a better *massecuite* than one of higher purity. However, the determination of the purity coefficient of diffusion juices is of practical value, in that it makes it possible to provide for the ultimate difficulties that may arise. Only when numerous purity determinations are made can one decide whether the purity of the juices will require the introduction of changes in the working of the battery, mainly as regards rapidity and increase of temperature.

CLAASSEN, discussing the question, says that these determinations are essential for the proper handling of the battery. They

* Oe.-U. Z., 30, 720, 1901.

are mainly important in case of frozen or inferior beets. With superior healthy and ripe beets it is doubtful whether the diluted juices of the last diffusors really have very low purities. By rational defecation and carbonatation the non-sugar may be separated and this epuration would tend to raise the purity. The syrups obtained at the expense of these epurated juices are rendered crystallizable after complete and exact neutralization, and the resulting sugar is obtained advantageously without extra cost of fuel or other items increasing the working expenses. Diluted, defecated and carbonatated diffusion juices always contain heavy percentages of alkaline carbonates which should be carefully saturated with carbonic acid when worked separately; but when worked collectively with the fresh diffusion juices, which is the case when the exhaustion is excessive, these carbonates have not necessarily any objectionable influence, but on the contrary are desirable for the following operation since defecated beet juices generally contain soluble calcic salts, which enter into double decomposition with the alkaline carbonates by precipitating as a carbonate of lime. When the defecated juices do not contain the soluble calcic salts a sulphuring of the concentrated juices exerts an excellent influence.

The limit of exhaustion for working diffusion batteries has been discussed by the Sugar Association of France. It was declared that the rational limit depends upon the composition of the juice in the last diffusor of the battery. These juices should be examined in the laboratory and submitted to a treatment such as they would undergo in the factory during practical manipulation, when a syrup is obtained it should also be examined. It is recommended further that some experiments be made in crystallizing these laboratory syrups. The limit of exhaustion of cossettes during diffusion should correspond to the limit of crystallization of the last juices obtained. It is asserted that the degree of purity of the final residuum molasses may be taken as a basis for the limit of crystallization.

KARLSON,* in discussing this question, points out that beets containing 15.8 per cent of sugar and having an average apparent purity of 82, exhausted so as to leave in the sweet water and in the residuum cossettes 0.54 per cent of sugar, give at that point an apparent purity of 61.2. The juices from the last diffusor should be constantly examined so that one may become perfectly familiar with

* D. Z. I., 25, 971, 1024, 1065, 1900.

the actual working conditions of the battery. These juices contain about the same percentage of calcic salts as the juices in the other diffusors, but comparatively little sugar, and they constantly, though unnecessarily, introduce lime salts into the juices circulating through the other diffusors. Waters from the last diffusors contain the same percentage of salts as does molasses. An important experiment has been made which consisted in mixing the juices from the first and last diffusors of a battery. These juices were subsequently epurated and concentrated until they had a consistence corresponding to that of a *massecuite*. They were compared with juices from the first and last diffusor treated in the same way but separately. The conclusions drawn were those possible to determine in advance by calculation. It is now declared to be inexact to assert that the amount of melassigenic non-sugar contained in the juices of all the diffusors is the same. Practical experiments show that the crystallizing powers of all the substances of which beet juices consist are nearly identical. If they are not exactly the same they have nearly the same ultimate purity. A purity of 60 in the last diffusor of a battery appears to offer the best results and will leave 0.6 per cent of sugar in the residuum water and cossettes.

On this point PELLET * says that the determination of purity of diluted saccharine solutions is very uncertain. With 3 grams of pure sugar dissolved in one liter water the purity will be 66.

KARLSON † does not agree with CLAASSEN in many of his arguments regarding the subject, and sugar experts generally are advancing very contradictory views in regard to the best way to work a diffusion battery. One authority claims that if 0.5 per cent of sugar is allowed to remain in the exhausted cossettes the juice in the last diffusor may have a purity coefficient of 63 to 70, but will subsequently crystallize with difficulty. It is evident that the data furnished by many chemists upon the question of limit of exhaustion only apply to some special cases and cannot be considered as general. When the sweet water from presses or the waste water from battery contains an exceptional percentage of sugar it is advisable to force this water back into the battery. In making calculations as to the most profitable mode of working a battery it must be remembered that, while on the one hand, the juice from cossettes is more readily worked if not thoroughly exhausted, on the other hand, excessive

* B. As., 14, 1090, 1897. † D. Z. I., 24, 1561, 1899.

exhaustion gives more sugar in the juices, though a large portion of this finds its way into the residuum molasses, making the economy doubtful. It would be unwise, however, to go to the other extreme and not exhaust the cossettes sufficiently.

Of late the theory has been advanced that the residuum cossettes should be allowed to retain considerable sugar. In the work of sugar extraction by the STEFFEN-BAERMANN * process it is to be noted that 3.5 per cent of sugar remains in the residuum. Under these circumstances the process appears to be not that of making sugar but of producing a cattle food. Through these conditions the total output of sugar of a factory will be decreased by 25 per cent, and this would evidently have an important influence upon the market price of sugar. The sweet water from the diffusion battery is entirely done away with and all questions as to purification, etc., need not be considered. What would be the financial results for those who had invested their capital in the enterprise? Would the money return be the same as hitherto? For this country, where the residuum is used for cattle feeding only in exceptional cases, it is evident that the new STEFFEN process does not offer any advantage.

DEGENER declares that it is a mistake to exhaust the beet slices beyond a certain limit, as the selling price of sugar is too low to compensate for the disadvantages that follow. Let the juice be of a quality equal, but not inferior, to molasses. The price of labor and many other expenses will thus be saved. The additional sugar left in the residuum cossettes renders them so much the better for feeding purposes.

These views have very little practical value. The losses in the sweet water, etc., would be considerable in standard batteries, and it is very doubtful if the diffusion juices obtained by such a process would have the high purity claimed. The diluted juices of the last diffusor have a purity of 70 and could be satisfactorily worked. They contain potassic and organic salts which form insoluble calcic compounds. The method would evidently yield less sugar and less molasses, and the increased nutritive value of the residuum cossette is a matter of conjecture. The views of most of the leading authorities are very contradictory on the subject of the most desirable limit of exhaustion. In many beet-sugar factories the limit is 0.1 per cent of sugar, while in others it is 0.4 per cent. Without attempting to decide the

* D. Z. I., 24, 1163, 1899.

question as to whether very dilute juices in the last diffusors may be purified as readily as when the residuum cossettes contain more sugar, it is important to note that when the exhaustion is pushed to extreme limits, the volume drawn off from the diffusors is greater and consequently there is more water to be evaporated. On the other hand, if 0.5 per cent of sugar is left in the residuum cossettes many experts consider the working faulty, but if about 0.3 per cent is allowed to remain the working is said to be most satisfactory. To this must be added the sugar losses in the residuary water from the diffusion battery, which gives a total loss of 0.5 per cent. Hourly laboratory examination of this residuum will indicate the conditions existing and any irregularities in the workings may be corrected before it is too late. Under no circumstances should it be forgotten when considering the question of the exhaustion limit that the problem varies with the locality and the circumstances. For example, with thick and badly cut beet slices the exhaustion never is and never can be as satisfactory, either as regards the sugar extracted or the non-sugar obtained at the same time as with fine and regularly cut cossettes.

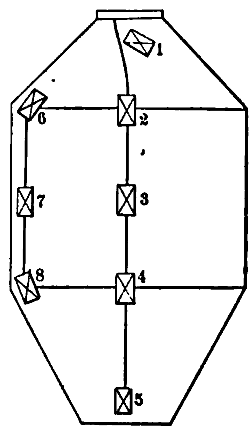

FIG. 141.—Arrangement of FOGELBERG Test Baskets.

Experiments on the exhaustion of cossettes placed at different parts of the diffusor have led to very important conclusions. The Swedish engineer FOLGELBERG * experimented to determine at what centres of a battery the cossettes were the least exhausted. Eight wire baskets firmly attached were suspended in a diffusor of 8000 liters capacity. Their arrangement is shown in Fig. 141, and the results obtained given in the table herewith speak for themselves.

It has been demonstrated that in accordance with the natural phenomenon the cossettes become gradually richer in sugar from top to bottom of the diffusors, so that when reaching the perforated false bottom they contain 0.1 to 0.2 per cent more sugar than they did at the top. When the perforated disk is conical, as is the case when emptying from the bottom, the sugar exhaustion at the centre of the conical portion may be very poor, especially when the greater

* C., 6, 734, 1898.

EXPERIMENTS WITH THE FOGELBERG TEST BASKETS.

| Number of Experiment. | Polarization of Cossettes. | Number of Basket. Polarization. | | | | | | | | Average Exhaustion of Cossettes. | Temperature of Battery | Drawing off per Diffusor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | |
| | | | | | | | | | | Per cent | ° C. | Liters. |
| I | 13.7 | 0.32 | 0.32 | 0.43 | 0.43 | 0.54 | 0.40 | 0.46 | 0.46 | 0.42 | 75 | 4700 |
| II | 13.7 | 0.36 | 0.37 | 0.37 | 0.37 | 0.52 | 0.40 | 0.40 | 0.49 | 0.41 | 70 | 4700 |
| III | 13.1 | 0.35 | 0.35 | 0.35 | 0.35 | 0.43 | 0.37 | 0.37 | 0.37 | 0.37 | 70 | 4800 |
| Aver. | 13.5 | 0.34 | 0.35 | 0.38 | 0.38 | 0.50 | 0.39 | 0.41 | 0.45 | 0.40 | 72 | 4733 |

part of the juice has already run off through the holes forming the upper part of the filtering cone. In very large diffusors it is frequently noticed that the cossettes which appear to collect in the upper corners of the apparatus are the richest in sugar when the upper cone adjusted to the cylindrical portion of the diffusor is of a more or less plane section. All these differences in exhaustion are less apparent with excessive limits of extraction, but become very evident with poor exhaustion, when the cossettes retain on an average 0.5 per cent of sugar or even more. These facts offer an argument in favor of pushing the exhaustion as far as possible.

CLAASSEN calls attention to the modifications which may have resulted from the varied composition of the beets. The changes necessitated by handling beets of different compositions in a battery working under varied conditions still remain an open question. Sugar, which is the principal component of the beet, does not undergo a perceptible modification even when the work is conducted slowly, because, as numerous experiments have already demonstrated, the increase of invert sugar is often doubtful. It is never certain whether the small increase of invert sugar was produced in the diffusion battery, with a corresponding decrease of sucrose, or if other constituents of the beet have created reducing substances. The amount of these reducing substances in diffusion juices is generally 0.5 to 0.15 per cent, depending upon the character of the beet.

Apparently there remains a higher percentage of albuminoids in the residuum cossettes when worked at high temperatures. The acidity of diffusion juices undergoes very little variation. The acid reaction is partly attributed to acids and acid salts of potash, which were either already dissolved in the beet or were dissolved during the operation of diffusion. The amount of pectic substances

and the partially soluble potassic and lime salts increase with the duration of diffusion and the number of diffusors of which the battery consists.

The fertilizers used in cultivating the beets and their degree of maturity have a very appreciable influence upon the solubility of these substances. A higher percentage of non-sugar is always extracted from beets that have been fertilized with excessive amounts of potash and nitrogen than from those cultivated rationally with the requisite amount of plant food and no more. A rational use of phosphoric acid plays an important rôle. Beets grown under the first mentioned condition contain considerable amounts of those substances in their composition, hence there follows a great difficulty of exhausting the beet slices of their sugar in such cases. To obtain a reasonable result the batteries must be run at a high temperature, the operation lasting for a considerable time. The substances contained in rotten or frozen beets undergo important changes during diffusion and the percentages of invert sugar, acids and pectic substances increase.

**Perturbations in the working of a diffusion battery.**—The perturbations in the working of a diffusion battery may be of various kinds, those of most frequent occurrence including difficulty in exhausting the cossettes of their sugar, stoppages from various causes, leakage and loss of sugar, breaking of the apparatus and other accidents. Difficult exhaustion may be due to various causes, such as faulty circulation in the battery when the beets are of an exceptional quality, or have gone to seed the first year or have wilted. Without doubt the working of a diffusion battery can be very much retarded by hand ing beets that have gone to seed the first year. Such roots being very fibrous the blades of the slicers soon become clogged and do their work badly. Special knives must be used for the purpose. Generally such beets are worked only at the beginning of the campaign when the early matured roots are delivered at the factory. The going to seed the first year is very frequently caused by a retard in the vegetation, or may be due to poor selection, abundance of fertilizers, or other causes.

Claassen very correctly says that certain perturbations in the diffusion demand modifications of the standard mode of working. These variations may be necessitated by the nature of the beets, neglect by the person in charge, or to a sudden interruption of the continuity of the work of the factory. One of the most difficult problems is to so regulate a diffusion battery that the handling of

partly rotten beets, or beets that throw off gases, will not retard the general working of the entire plant or cause juices of excessively low purity.

Beets that are thoroughly frozen do not thaw during water transportation to the factory or in the beet washer, and to remove the adhering dirt in the washer is about all that can be done. It is not possible, under such circumstances, to obtain superior cossettes. The ordinary slicing blades cannot be employed and one must resort to the use of the so-called finger-ridge knives, which are better than the flat-finger types. Under these conditions short bits of cossettes are obtained together with a pulp-like mass which gives much trouble in the diffusion battery. Frequently these slices from frozen beets freeze into a compact mass that will not thaw even when mixed with hot juices, and when a diffusor is emptied these blocks of frozen cossettes are found side by side with those which have been properly exhausted. To overcome this difficulty as far as possible, it is recommended to introduce juice at a high temperature from the bottom of the diffusors before and during the filling. In the other diffusors of the battery the working temperature should be comparatively low for the reason that the cellular tissue of the beet is already partly destroyed through the action of the cold and these cossettes readily become soft. Consequently if the temperature in the battery is diminished proportionately to the amount of frozen or spoiled beet slices being handled, the circulation will be reasonably satisfactory. It is evident that when obliged to work under these conditions a very irregular exhaustion of the cossettes will always follow. As of two evils the lesser should be chosen, it is better to risk the possibility of a greater loss of sugar than to attempt to work at a higher temperature, thereby completely stopping the circulation. Furthermore, a greater loss of sugar is of little importance in comparison with the possible alteration in the composition of these juices, which is always to be dreaded when working at a high temperature.

**Faulty circulation.**—Among the accidents and perturbations which may occur during the working of a diffusion battery the most frequent is the faulty circulation of the juice. The main cause of this is overheating in one of the diffusors, for which the battery man is generally responsible, as it is traceable to the faulty handling of the calorizator or some inattention. When the exhausted slices are bright yellow it gives rise to apprehensions that there is overheating and the resulting complications may last for hours.

If the excessive temperature is noticed in time it may be desirable to introduce some cold water into the superheated diffusors and to force a rapid circulation so that the cossettes will be under the influence of the high temperature during the shortest possible time.

It frequently happens that a beet slicer is working when nearly empty. The resulting cossettes are very poor and if they fall on the perforated bottom of a diffusor they stop up the holes. In this case it is well to bring the slicer to a standstill until the feeding hopper is full of beets. It may also happen that the difficulty arises from the faulty working of the slicing blades; if so these should be changed at once. It is mainly during the first filling of the diffusor that these troubles are most to be dreaded. In arranging the diffusors in a battery it is essential that the circulation of the juice have as few obstacles to overcome as possible, and with this in view the following precautions are adopted:

Increase of the water pressure on the last diffusor;
Decrease of the counter pressure in the measurer;
Increase of the section of the piping and valves;
Complete elimination of air;
Increase of the openings of the perforated bottoms.

Of all these expedients the most effectual generally is the increase of free passages in the perforated bottom. A decreased rapidity of circulation in the battery may also be caused by a diffusor having been improperly emptied, and when the new beet slices are added their pressure on the exhausted residuum remaining may be sufficient to completely stop up the holes of the perforated bottom. Therefore, it is important that the battery man should see to their removal. MALANDER says that when this difficulty occurs there is no way to overcome the trouble and bring about an active circulation. Even abnormal heating produces very little effect. The existence of the difficulty is made evident by the abnormal time that is needed for the mashing and drawing off. One of the best evidences of this clogging is the indication on the pressure gauge attached to the calorizators, which will show a striking difference from those of the other diffusors. Automatic registers connected with the measuring tanks always show that the irregularity exists. When pressure gauges are placed on the water pipe of the diffusors the difficulty may be located by successively opening for an instant the water valves on each diffusor of the battery; the pressure will fall very considerably as soon as

the clogged diffusor has been passed. If the difficulty occurs in one of the diffusors near the end of the series it may be desirable to throw the compartment out rather sooner than was intended.

The pulp separator which is frequently placed between the measuring tank and the battery sometimes becomes overcharged with the suspended particles of pulp, and this fact is made evident by the time required for drawing off being comparatively longer than that needed for mashing. Then again the faulty circulation may be due to the air that has collected on top of the diffusor and the preceding calorizator. A large quantity of air has a decidedly objectionable influence on the circulation of the juice in the diffusors, and this is explained by the fact that the juice circulates from top to bottom while air or gases have a tendency to rise. Thus when air or gases exist in excess throughout the entire diffusor considerable resistance to the circulating juice is offered. When air is present in sufficient quantity to reach the lower level of the communicating pipe, the juice can no longer circulate and the air cannot descend to the bottom of the diffusor. Every possible means which will tend to permit this air to make its escape should be adopted. For this purpose special cocks are used on the upper part of the diffusor, or better still an automatic purging appliance may be employed. Under ordinary conditions, and when the working is conducted only through water pressure, these purging appliances are not absolutely necessary. However, if the juice is forced from the last diffusor with compressed air, it is possible that air may find its way into the other diffusors by leakage of the valves. These appliances may also render excellent service when there is an escape of gas during diffusion. Whether the circulation in general is satisfactory or not it is desirable that a pressure gauge be adapted to the pipe through which the forced juice circulates, as it gives a positive indication every instant of just how the circulation is progressing, at which point the pressure is least and where the greatest pressure should be overcome. It is not the air only which causes the perturbations under consideration as they may be produced also by fermentation in the battery. At times there is produced a phenomenon very like a fermentation if the beets contain considerable air in their tissue which only partly escapes when the juices are brought in contact with the beet slices. These gases are rich in carbonic acid, but they are not formed during diffusion and are too limited in volume to cause much trouble. They may be allowed to escape from the upper part of the diffusors where they gradually collect.

**Fermentations in the battery.**—The fermentations may cause serious irregularities in the circulation. CLAASSEN says that the generation of gases in the battery is a difficulty which occurs less often with the present modes of working, which are generally rapid and at a high temperature, than formerly when the slow, cold process was used. The cause of the froth formation is in reality a liberation of gases, mainly hydrogen produced during fermentation. Up to the present time there is no very satisfactory explanation for this fermentation, although experience shows that it is more general when working dirty beets or using very impure water in the battery. That the micro-organisms are introduced into the diffusors by the earth adhering to the beet slices or by contaminated water appears reasonable. The fact is that during the operation of extracting the sugar from the beet the resulting juices are likely to be infected by various micro-organisms.

SCHOENE'S* investigations tend to point to the fact that the greatest number of bacteria are found in the diffusor using fresh water, the fewest being in the centre of the battery, and even in defecated juices these spores have been found. The number of micro-organisms increases in concentrated juices, but special filtration may help to eliminate a great number. During graining in pan they may or may not be present in large quantities. Lactic or butyric ferments have not been noticeable, but, on the other hand, the leuconostoc-mesenteroides are to be found in all juices. Streptococcus are found in considerable number in limed and very hot juices and attack the sugar with considerable energy.

BRENDEL thoroughly examined every part of the diffusion plant, including the slicer, pipes, etc., and found a glue-like deposit. The filters for raw diffusion juices were also examined; upon close examination of the unmounted frames there was discovered a granulated mass which was made up of leuconostocs. After a thorough cleaning and disinfection the filtration was resumed and the same microbes were again found. The fresh juice contained 10.68 per cent of sugar and had a purity of 82.8, while after an interval of two hours the sugar percentage was 8.48 and the purity coefficient was 66.3. The same juice which had been properly treated with sub-acetate of lead underwent no change. Whether this loss was due to micro-organisms is still an open question. A well-known

* Z., 51, 453, 1901.

chemist, determining to ascertain from special experiments the exact influence of the leuconostoc, mixed fresh diffusion juices with these microbes and after nearly two hours found that the 0.50 per cent sugar loss was replaced by only 0.10 per cent inverted sugar. As to this loss of sugar it is said that while the micro-organisms may at first bring about an inversion, the invert sugar is soon transformed into lactic acid. In fresh juice without microbes only invert sugar is formed. It is only when the acidity increases that the leuconostoc influence decreases, the sugar transformation into invert sugar then increasing. All these facts considered it is extremely doubtful if there are any unknown losses when working a diffusion battery on a purely scientific basis. On the other hand during the manipulations that follow such as defecation and carbonatation any neglect by the person in charge might cause considerable loss. In some beet-sugar factories fresh diffusion juices are filtered before the lime is added, and there is always great difficulty in working these filters, as the filtering surfaces soon become clogged and the flow of juice is retarded and considerably cooled. During this period certain important transformations occur.

From what has been said it is evident that diffusion juices contain enormous quantities of micro-organisms introduced directly by the beet or by the water circulating in the battery. Beets have on their surface innumerable microbes, but these, with the exception of the thermophile microbe, are all destroyed at 60° to 70° C. But their spores will resist, and if the temperature is reduced to 30° to 40° C. will multiply very rapidly and decompose the sugar. During the normal working of a diffusion battery there need be no such losses, owing to the elevation of temperature and what is most to be dreaded is the stoppage during the work and the consequent cooling of the juices. Defecation and carbonatation check the propagation of these organisms owing to the high temperature at which these operations are conducted. Lime, owing to its caustic action, has a destructive influence. When the carbonatation has been conducted at a moderately high temperature only the clostridium may be distinctly seen. These microbes will develop in osmogene water, due to the fact that such waters contain considerable non-sugar, which is favorable for their growth; their vitality is such that they can resist a temperature of 90° C. for half an hour. The temperature existing in triple effects and vacuum pans tends to check the development of the microbe under consideration, but if the concentrated syrup is allowed to cool, the

clostridium, which may be accidentally found, will rapidly increase n number when brought in contact with the air. LEXA some time since discovered the germ of the clostridium in a fresh *massecuite,* and also in all the after-products. This authority does not attribute the entire inversion of sugar to these micro-organisms, but admits that they have a decided influence in that direction.*

For many years past the question of the fermentation of invert sugar during the working of a diffusion battery has been the subject of numerous discussions, owing to the unknown losses occasioned thereby, some authorities claiming that these changes occur during working while others maintain that to be impossible. Without taking the action of micro-organisms into consideration JESSER † claims that diffusion juices possess a special inverting tendency and that the invert sugar is formed at high temperatures. CLAASSEN ‡ points out that the increase of invert sugar during diffusion is from 0.10 to 0.17 per cent, while PELLET § maintains that invert sugar is neither formed nor destroyed during diffusion, provided the battery has been properly handled and that CLAASSEN's conclusions are the outcome of want of accord in the modes adopted for the examination of juices and beets. It is difficult to divide between these two experts.

The gases formed during diffusion are inflammable, and are said to consist mainly of hydrogen. Are they generated by the action of the acids of the beet juices upon the iron of the diffusors? BODENBENDER ‖ has pointed out that a certain quantity of carbonic, lactic, and butyric acid existed, and attributes their presence not to any biological phenomena but purely to a chemical action. FISCHMAN insists, on the contrary, that they are the outcome of fermentation. Analyses ¶ were made of the liberated gases from different diffusors, and it was noticed that where the juice was hottest and at the same time richest in sugar, the greatest amount of carbonic acid was always formed. These gases frequently contain as much as 60 per cent of carbonic acid. SCHEIBLER ** was the first to discover that the gases thrown off in the diffusors, under certain circumstances, contained hydrogen. OSWALD's †† analysis shows 9.9 per cent carbonic acid, 50.5 per cent hydrogen and 39.55 per cent nitrogen.

Many methods have been suggested to overcome this difficulty

* S. B., Sept. 1900.
† D. Z. I., 22, 22, 1897.
‡ C., 4, 793, 1896.
§ B. As., 15, 550, 1898.
‖ Z., 21, 117, 1871.
¶ Z., 21, 311, 1871.
** Z., 27, 66, 1877.
†† Z., 27, 272, 1877.

among which may be mentioned the use of formol, phenic acid and bisulphide of lime, but these were without effect. The use of lime tends to increase the bacteria formation, but hydrofluoric acid renders excellent services if properly handled, though there is always some danger of a partial sugar inversion. Fluoride of ammonium, when used in quantities of 10 to 12 grams per hectoliter of juice during the filling of the diffusors, prevents either lactic or butyric fermentation. This method is not practical on account of expense. Sulphuring the waters used in the battery so that they contain 0.15 to 0.20 per cent of sulphurous acid gas per liter has given most excellent results in several factories. CLAASSEN says that without doubt one of the best modes of handling gases in diffusors is the immediate emptying of all the diffusors of the series. The elimination of these gases by means of special cocks or other apparatus cannot be satisfactorily accomplished, as they only partially collect in the upper part of the diffusors while the greater volume remains as a sort of bubble at the centre of formation. The entire contents of the diffusors is consequently very frothy, which retards very considerably the circulation of the juices. However, the slower the circulation the greater will be the obstruction caused by the gases liberated, so that in the end the circulation ceases entirely. If, on the other hand, the battery is emptied and the diffusors are well washed out, this objectionable phenomenon rarely occurs, especially if the battery is worked from the start as hot and as rapidly as possible with few diffusors avoiding all stoppage of the circulation. The greater loss of sugar in the exhausted cossettes is more than compensated for by the more rapid working and the production of better juices, even without allowing for the unsatisfactory exhaustion in the diffusors filled with scum.

Care should be taken not to approach open diffusors with a light, as the gases liberated contain quantities of hydrogen which might cause an explosion. According to the investigation of a Belgian scientist * the origin of inflammable gases formed during diffusion has not been fully explained. It never occurs with perfectly healthy beets, but frequently with such as are frozen. The trouble may be obviated by thoroughly oiling the inner surface of the diffusor. Another apparently excellent remedy consists in keeping the leading diffusor at a high temperature. The experiments of

* S. B., Nov. 1883.

GAREZ * have demonstrated that if the juice drawn off is very hot it contains far fewer micro-organisms than when the usual temperatures are employed. SAILLARD † recommends washing the entire diffusion battery with a disinfectant before the working commences and cleaning the interior of the pipes with a plug saturated in bisulphide of soda, using one liter at 34° Bé. per ton of beets sliced.

**Perturbations caused by stoppages in other parts of the factory.**—The unsatisfactory working of a diffusion battery may be due to the irregularity of delivery of the beets at the slicer, etc. Upon general principles it is desirable to draw from the diffusors every half hour a full measure of juice and to empty a certain number of diffusors so as to maintain a slow circulation of the juice without too much non-sugar being dissolved from the exhausted cossettes. This method is not practicable when the perturbations are due to some subsequent operation in the process of sugar extraction. The alteration of beet juice is especially to be dreaded when the slowness of the battery's juice circulation is due to some defect in the working of the filter presses. One of the principal causes of slow filtration is the attempt to work beets which are not sufficiently matured or have been fertilized with an excess of nitrogen; or it may be due to the presence in the juices of pectic or similar compounds formed during defecation, which increase as the period of diffusion is prolonged. In such cases it is found desirable to reduce the temperature of the diffusion as low as practicable, doing everything possible to attain a satisfactory sugar exhaustion while keeping the diffusion at a temperature of 65° to 70°, under which conditions the filter process will work satisfactorily. Should the perturbation in question last more than twelve hours it would be well to empty the battery entirely and begin over again, after having eliminated the cause of the disturbance.

**Leakages and sugar losses.**—CLAASSEN very justly says that defective valves are also frequently responsible for the faulty working of a diffusion battery; for example, a water valve that does not close properly will always cause a certain dilution of the juices with water. For this reason the person in charge of the battery should assure himself, after each diffusor has been emptied, that all the valves are working properly, in other words, that neither water nor juice will escape from the pipe which terminates at the top of the diffusor. When vulcanized rubber or fibre is properly fixed

* J. d. f. d. s., **40**, No. 12, 1889. † B. Syn., **39**, 475 and 479, 1903.

to the seat of the valve, there need be no apprehension of this difficulty. At the beginning of a sugar campaign the joints and seats of valves that have become hardened during the summer months are frequently leaky, but after a few hours working they resume their normal condition. The valves should be repaired when the appliance to which they are attached is inactive, and the same may be said of leaks of all kinds whether in piping, calorizators or wherever they may be. When water and compressed air pipes are attached to a battery juice may make its escape by leaking into the water reservoir or the compressed air receptacle. MALANDER recommends that there be but one distributing pipe for the water of a diffusion battery. If two kinds of water are needed they may meet in front of the battery by means of a BLANCKE'S valve.

**Leakage in calorizators.**—It may happen that a calorizator leaks because of the bursting of a tube, in which case experience shows that it had better be entirely renewed rather than repaired; but a mere leak at the joints between the tubes and disks may be readily mended. To corroborate the existence of such leaks samples of the condensed water should be frequently taken from each calorizator. MALLEBRANCKE * has proposed, with a view to preventing sugar losses caused by leaks in the calorizators, to turn the pipe conducting the condensed water into the compartment containing the juice of the calorizator. The condensed water would thus carry with it into the juice all the sugar that may be in solution by reason of the leakage, and a very insignificant dilution of the diffusion juices would result. The question is asked, why not simply use steam injection which costs less than calorizators? As the water is to return to the juice this change demands a certain pressure which would do away with the characteristic feature of a calorizator, namely, the use of low pressure steam.

**Sugar losses through faulty manœuvres.**—The faulty handling of the valves, etc., of a diffusion battery may be the direct cause of serious sugar losses. For example, if the emptying valve at the beginning of a battery be opened instead of the one at the tail end of the series, or if the valves have not been closed at the proper moment considerable sugar losses may follow. As a general thing, as has been previously explained, this emptying pipe may be opened from above by the use of a long rod and its function is shown by a colored disk. It is claimed by some experts that an empty-

* S. I., 17, 546, 1881.

ing cock is more desirable than a valve as its working may be more readily watched. Numerous combinations and devices have been arranged to prevent errors of this kind. HOENE * has a signal apparatus attached to the vertical rod of the emptying valve of the diffusors, the signal giving the alarm during the entire period that the valve remains partly open. The sheet-iron disk of which the alarm signal consists may be arranged in such a way as to cover the hand wheel working the valve for mashing as long as the emptying pipe is not entirely closed. By this combination the mashing cannot be accomplished until all is in order, and no juice need be lost. The fault to be found with all such arrangements is that they introduce a new complication into a situation that already demands close attention, but after a time the manipulation of these valves requires no further thought, being managed by the battery man almost automatically

**Bursting or breaking of an apparatus.**—Sometimes accidents occur by opening a diffusor that is under pressure. The door might be swung back with such force as to break it. Numerous suggestions have been made for the prevention of such mistakes. In order not to render an entire battery inactive when an accident necessitates the removal of one diffusor from the series, a syphon-shaped copper pipe may be used which is attached to one calorizator and the connection valve of the following one, thus bridging over the diffusor whose working is faulty. In some specially constructed calorizators provision is made for special pipes to meet such emergencies. Under all circumstances control of the battery by repeated chemical analyses is necessary, and this must be kept up night and day as the slightest neglect might cause numerous complications.

**Epuration of juices in the diffusion battery.**—For many years past repeated efforts have been made to accomplish an epuration of beet juices in the diffusion battery, and numerous chemicals have been suggested which would accomplish this and in a measure prevent fermentation, but generally the results obtained have not been up to expectations. Of all the products and chemical agents used lime and sulphurous acid have been most popular for the reason that they may be had at reasonable prices, which is always an important factor when the issue is a practical one.

Lime neutralizes the natural acidity of the beet and prevents

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* Z., 49, 892, 1899.

the formation of invert sugar. Evidently a certain epuration must result. It has recently been suggested by BESSEKERSKI * that the juice in the beet cells should undergo epuration before being treated in the customary manner. With this idea in view an attempt is made to utilize the tissue of the cell proper as a filtering medium. To the fresh beet slices 2 per cent of pulverized quicklime is added, and they are then emptied into the diffusors of the battery. The cossettes become white in color and give a pure clear juice, still retaining 0.06 per cent of calcic oxide without pigment. The juice will readily crystallize and the losses are no greater than by regular modes. The objectionable feature is that the final residuum cossettes cannot be fed to cattle. Investigations are now being made to determine some way to overcome this difficulty.

ANDRLIK † attempted to increase the filtering powers of beet juices by eliminating the albumin, and this is accomplished by using in the battery water containing 0.32 to 0.70 per cent of oxide of calcium. With less than 0.4 per cent the liquor cannot be filtered; with more lime, that is to say with 1 per cent and over, filtration is possible, but the quality of the juice is injured as the lime dissolves a portion of the beet cellules, and in all cases the lime percentage of the beet slices becomes excessive. It is thought that with sufficient lime to render filtration possible the quality of the resulting residuum cossettes would be reduced, and that, furthermore, they would become decidedly objectionable for cattle feeding.

**Sulphurous Acid** has been suggested by many experts for epurating purposes. SCHEERMESSER ‡ recommends that water saturated with sulphurous acid be used as the final water in a diffusion battery. The cossettes that have been thus treated are subsequently readily pressed and contain 1 to 1½ per cent more dry substance. The sweet water contains as much sugar as before, but the hydrometer reading is only 0.9 Brix instead of 2.9 Brix. This is due to the coagulation of the albumin in the cossettes. Strange as it may seem these sweet waters do not ferment and even after nine months show no evidence of froth on the surface. It is claimed that the pressed cossettes when aired soon lose their sulphur odor. Other experiments of the same kind have come under the writer's notice, in which the ultimate *massecuite* was purer and contained a smaller percentage of organic matter than by ordinary methods of working,

* C., **10**, 998, 1902. † C., **10**, 816, 1902 ‡ Z., **50**, 961, 1900.

the purity coefficient reaching 96. During defecation the lime added precipitates the inorganic salts, while the excess of sulphurous acid combines with the lime to form a sulphite of lime.

It is doubtful whether such cossettes could be fed to cattle with any success, for the slightest odor of sulphur would be sufficient to cause the residuum to be absolutely refused by live stock in general.

**Bisulphide of lime.**—Among the numerous other forms under which sulphurous acid has been used in diffusion batteries there may be mentioned bisulphide of lime as suggested by VIVIEN.* This method was in vogue for some time, and it was claimed that the juices obtained by it had an exceptional purity. According to LACHAUD the treatment resulted in a very appreciable organic epuration. The bisulphide was run into the diffusor during the entire period of filling. On the other hand BATTUT pointed out that this mode necessarily caused some degree of sugar inversion. But very recent investigations show that sulphurous acid has less action on sugar than was at first supposed. In this special case, however, there would be some danger of sulphuric acid being formed. On the one hand it would invert the sugar, and on the other combine with lime to form a sulphate subsequently causing deposits upon the tubes of the calorizators.

**Hydrosulphide of soda** may be classified in the same category of epurating agents. SCHILLER † recommends that hydrosulphide of soda be added to the second diffusor of a battery so that the juice's acidity becomes 0.5 to 0.8 per cent per liter. The precipitated albumin finds in the cossettes of the first diffusor an excellent filtering medium. The juice is heated to the boiling point which necessarily sets free the sulphurous acid and the volatile organic acids. Lime is added until there is an alkaline reaction, filtration follows, and then a second saturation with 0.25 per cent lime.

**Carbonate of soda** has been used to neutralize the acidity of juices and present sugar inversion; furthermore, the soda precipitates the calcic salts of the juice, resulting in sodic combinations which do not obstruct the sugar crystallization.

**The sodic baryta** method of DU BEAUFRET consists in using soda and baryta in the diffusors. The battery is at a temperature of 75° C., the beet slices are sprinkled with sodic carbonate so that the juice is slightly alkaline; to the juice drawn off, when in tank there is added 1.9 kilos of baryta to juice at 17° Brix; it is

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* BEAUDET, Traité, 1894, p. 195.

† C., 6, 951, 1898.

then heated at 85° C. 50 liters of milk of lime at 22° Bé per 10 h.l. of, juice are added before the first carbonatation and 15 h.l. of juice before the second carbonatation are also combined with the same volume of milk of lime. The heating must not exceed 85° C. The alkalinity of first carbonatation should be 1.2 grams of calcium oxide per liter and 0.15 per second. This process was temporarily popular but is no longer in use.

**Silicates** for diffusion epuration have many advocates, and among the different processes may be mentioned that of HARM,* in which the epuration is accomplished by the use of certain clays containing silica which readily combines with other substances. It is proposed to place near the beet slicer a silicate distributor, the chemical to be mixed with the fresh cossettes in the proportion of ½ per cent. Silica combines with the alkalies, and these salts being precipitated and other impurities eliminated at the same time, the resulting juices become very pure and require very little lime in subsequent operations. If these assertions are true a higher sugar percentage and less final residuary molasses will necessarily result. The presence of silicates in the residuum in no way diminishes the value of the molasses for feeding purposes, and it is said that the economy resulting from the use of the lime pays for the entire cost of the operations.

RUEMPLER † has given the subject of silicates some attention and states that certain natural silicates containing water and known as zeolithes, also composed clays, such as *bolus*, cement decomposed by water and double silicates have the property of fixing potassium and abandoning in exchange the metals they contain, such as lime, magnesia, and sodium. The reverse is also true. Silicates may have a destructive action upon beet juices when the beets have not been properly washed and the adhering earth is sent with the cossettes into the diffusion battery. The purity of the diffusion juices may be lowered if silicates rich in akaline salts find their way into the diffusion battery. If silicates were simply mixed with the juice it would be impossible to remove all the potassium introduced. If a silicate is obtainable that is absolutely free from potassium theoretically all the potassium may be removed from the solution by simply filtering through layers of silicate.

**Other epurating agents.**—Besides the chemicals already men-

* D. Z. I., 25, 591, bis 1900. † D. Z. I., 26, 585, 1901.

tioned numerous other substances have been experimented with as epurating agents. None of them has been given a practical trial, as but few have ever passed the laboratory stages. Not long since in the sugar world attention was attracted to some mysterious powder which was added to beet slices. The resulting juices were worked with 1½ lime during carbonatation and the purity became 94.4. The low-grade products were satisfactory. The residuum pulp was eaten with avidity by cattle and was readily kept. No practical results, however, have ever been obtained with any of these experimental substances, and the epuration of beet juice, as an issue, should be kept entirely separate from the process of diffusion, which when properly managed gives excellent results.

**A general synopsis** of the essentials for the successful working of a diffusion battery, as given in the foregoing, is as follows: An even distribution of the cossettes, which should have a special shape, the temperature of the battery should be regulated, and the rapidity of flow from diffusor to diffusor determined by experience. Each compartment of the battery should be as full as possible, care being taken to avoid jamming. Precautionary measures in this special work are always followed by considerable increased yields. It may be noticed that the slices frequently collect in lumps, between which the juice circulates freely, not becoming thoroughly saturated. The use of a large fork, properly handled, produces the desired uniformity during filling. The shape and clean cutting of the cossette has a greater influence than is generally supposed. If they are too large the inner cells are not reached by the circulating juice, and this is also true if too small, for then they tend to clog and cook; their adherence is frequently such that they offer considerable resistance in the residuum cossette presses. The knife regulation is a difficult issue. The temperature, etc., of the battery must be considered, as it has a great influence on the density of beet juices; if too high, the juices are very impure, other substances than sugar being then dissolved; the temperature varies with the quality of beets being worked. Rapidity of working appears to give general satisfaction, as juices are then purer and the efficiency of the apparatus is greater. Some experts are no longer in favor of injectors or the use of live steam for reheating juices between diffusors.*

* S. B., June, 1899.

## CHAPTER III.

### EXHAUSTION OF COSSETTES AND THEIR DRYING

**General remarks and considerations.**—The main object of the sugar manufacturer is to extract from the cossettes as much sugar as possible and to leave behind a maximum of albuminoids and other substances which, however, are likely to offer difficulties during the subsequent operations. The exhausted cossettes will ultimately consist of a residuary product which is of great value in cattle feeding.

As all the substances dissolved in the liquid of the cells are known and also the order in which they diffuse we are able to approximate with considerable accuracy the composition of the exhausted cossettes. They are poor in sugar and relatively rich in albuminoids and pectic substances. The salts also are eliminated to a great extent, and as the product leaves the diffusion battery it has about the following composition:

COMPOSITION OF COSSETTES AS THEY LEAVE THE DIFFUSION BATTERY.

| Substances. | STAMMER. | BRIEM. |
|---|---|---|
| | Per Cent. | Per Cent. |
| Water | 95.45 | 94.0 |
| Cellulose | 3.32 | 1.4 |
| Albuminoids | 0.36 | 0.5 |
| Ash | 0.30 | 0.4 |
| Extractive substances | 0.57 | 3.6 |
| Fatty substances | ........ | 0.1 |

It is very evident that these figures are not absolute. They vary with the original composition and physiological condition of the beets which allow diffusion to take place more or less rapidly, thereby permitting the dissolved substances contained in the cellular tissues to pass through the outer walls at a more or less rapid rate.

The composition furthermore depends upon the method of manu-

facture, the process of diffusion and the degree of exhaustion to which the beets have been submitted in the diffusion battery. Suffice it to say that there are many sugar factories which allow 0.8 per cent of sugar to remain in the residuum, while at other factories the limit is 0.15 per cent; DEGENER favors leaving about two per cent.

What strikes one especially in these data is the enormous quantity of water remaining in the residuum and every effort should be made to reduce this to a minimum. It stands to reason that such excessive amounts must be deleterious to the general health of the animals to which it is fed. The methods proposed to reduce the water percentage are very different, but as they depend essentially upon the conditions in the various factories in which they are used details cannot be given. It is customary to resort to a mechanical method by which the water is reduced at least 50 per cent.

The desirability of entirely eliminating the water of diffusion pulps is an open question. When the product is to be consumed near the beet-sugar factory it may be thrown into silos upon leaving the battery and the water will be pressed out by the weight of the mass. This plan would not be practicable, however, when pulps are to be carried to distant farms, hence generally reasonable pressure is desirable. The ordinary method of straining the cossettes and allowing the water to drip off gives only fairly satisfactory results. Some allow the water to drain off upon inclined planes; the semi-strained mass is then laid on wagons and the dripping continues. Under these circumstances only 60 per cent of the water separated by the standard presses is obtained. According to WICKE the residuum thus obtained contains 8.5 per cent of dry substances. On the other hand, BODENBENDER, who has also made some experiments in endeavoring to drain water from the residuum, has obtained strained cossettes containing 85 per cent of water. In these same pulps the weight is reduced to 50 per cent after siloing, which would tend to confirm the argument of SCHOTTER, who held that pressing was not necessary when the residuum was to be kept for more than eight months. He claimed that after this time, pressed or not pressed, the residuum always had the same composition.

The straining method has very little practical value for large factories, and it is now customary to submit the cossettes to considerable mechanical pressure upon leaving the battery. To accom-

plish this an almost unlimited number of cossette presses has been invented, but the results obtained with them are approximately the same. When first introduced they gave a residuum containing 9 per cent of dry substances. Little by little the improvements resulted in an increase in this percentage, a greater quantity of water being expressed. As a result 15 per cent of dry matter are attained in the best-known apparatus, and this is by no means the limit that such machines may attain.

There are, however, certain obstacles to be overcome before the desired result can be realized. Excessive pressure would reduce the cossettes to a paste, and this would be objectionable, as a certain dry pulverulent condition of the ultimate product is desired. This is the consistency generally possessed by the cossettes after they leave the typical presses and in this form they are easily handled. Furthermore, such a paste would pass through the perforated iron filtering surfaces of the presses and obstruct their proper working. An excessive pressure would also decrease the percentage of nutritive elements, as some would be carried out with the sweet water escaping when the sides of the beet cells are broken open.

**Transportation to lift.**—The exhausted cossettes emptied from the diffusors at the side or at the bottom are received either on an endless horizontal band carrier, spiral carrier, or in a receiving receptacle of considerable capacity, the sides of which may be vertical or very slanting. If water is lacking the last diffusors may be emptied with compressed air, the cossette receptacle being no longer of the same use. Under these circumstances one is obliged to perform the tedious work of handling a residuum that is considerably pressed in the diffusor and must be emptied from the side. Rapid emptying by the use of compressed air introduced at the top of the diffusor is not a success. In modern beet-sugar factories flumes or sluices are generally used for the transportation of the residuum cossettes after they leave the battery. The remarks made in a previous chapter on the transportation of beets are applicable here. To calculate the capacity of the flumes the volume of the diffusors should be taken as a basis, their width and depth of course increasing with the size of the battery.

Notwithstanding the fact that the cossettes are thrown from the diffusors with considerable force, and that the greater percentage of their weight is water, it is generally desirable to introduce water in the upper part of the receiving flumes. For this purpose it is well to employ sweet water, which after being separated from the

residuum by suitable straining devices may be pumped into a reservoir and again used. MALANDER says that in factories coming under his notice an angle of 6° for the slant of the residuum cossette flumes gives very satisfactory results. Evidently if these sluices are very slanting the residuum cossettes will be carried forward without the addition of water.

Another system of diffusor emptying, which includes the elevation of the slices, is based upon the introduction of compressed air at the bottom of a closed diffusor. The mass of cossettes is thus well stirred up and do not adhere at the bottom to the metallic strainer. If at the same time a large lower valve attached to the bottom is opened all the contents are forced through a special pipe into the cossette presses, providing the desired pressure is attained in the battery.

**Lifts.**—There are no special points to be noted in the general construction of the residuary cossette lifts, when the excess of water has in a measure been removed. In most cases such a lift consists simply of a band with small wooden attachments on its surface. Near the lower drum on which the band turns is a scraping device which removes all adhering cossettes, for if they should find their way between the drum and the band it would slide upon the pulley. For lifting the exhausted cossettes from the flumes a bucket carrier may be used which collects the residuum in a cemented cistern, the capacity of which corresponds to that of a diffusor. In the smaller factories the motion of the bucket carrier suffices to keep the cossettes well suspended in the residuary water and at the same time assures their regular removal. The sides of the receiving cistern should be almost vertical, notwithstanding the fact that in most cases the cisterns have a comparatively slight inclination. Experience shows that it is not desirable for the cistern to be any larger than is actually needed, as otherwise the pulps are not all taken up by the bucket or the pockets of the carrier. When they are pushed beyond the reach of the carrier the man in charge should see that they return to the proper place. Difficulties frequently arise when the pockets or buckets in question are not sufficiently filled with cossettes or when the cemented receiver or cistern is too large. Complication also occurs when the water introduced is excessive or attains too great a depth in the interior of the cistern. This difficulty may in most cases be overcome by reducing the capacity of the water reservoir and its automatic overflow or by shaping the receiver so that it will

force all the residuum into the pockets of the carrier. The carrier is heavily loaded every time a diffusor is emptied and in the interval works almost empty. In order to reap the advantage of the large receptacle for the homogeneous distribution of the cossettes a horizontal revolving shaft with arm attachments should be placed at the foot of the carrier, and the cossettes will be constantly forced into the pockets.

Generally the cossette lift has a slanting position, the advantage being that the water which finds its way through the perforated iron buckets will not fall into the pockets of the carrier beneath. The residuary water, which must also be removed from the receiving cistern, is simply allowed to run off by gravity. The suspended pulps are separated by suitable iron strainers. To prevent these from becoming clogged they are placed near the carriers, the buckets of which occasionally rub its surface and keep the perforations entirely open, the water then flowing freely towards the decanting tanks. Behind these strainers is an overflow which has a tendency to modify the velocity of the dirty water running off and also the quantity remaining combined with the cossettes with which it comes in contact. Evidently the greater the volume of water in the cisterns the more readily will the cossettes remain in suspension. Instead of the endless band and bucket carrier a spiral may be used to press the cossettes during their transportation. But the pressure attained by this endless screw is not sufficient if the cossettes are to be subsequently dried. In the arrangement shown in Fig. 141 the first portion of the slanting spiral is in a cylinder. The cossettes enter at *A*, the spiral *B* carries them forward and the water separated falls through *C*. From this point on the outside receptacle is conical. The entire shaft *a* receives its motion from a suitable gearing *b*. The semi-compressed pulp falls into the hopper *D* and from there to the cars *E*.

[Under another caption the Pfeiffer compressed-air mode was described. (Fig. 132.) The residuum cossettes are raised to the receptacle *A*, from which they fall upon the spiral *B*, which raises them above the hopper of the cossette press.]

**Cossette Pumps.**—By the Limpricht * (Fig. 142) mode the residuary cossettes are raised from the flumes to an upper elevation by means of suitable pumps. The pressure in the sluices is sufficient to carry the water and cossettes into the main body of the

* Oe.-U. Z., **30**, 782, 1901.

pump without the necessity of any valve attachment. The piston *e* closes the opening *c* and by the next stroke forces the residuary water and cossettes through the connecting pipe with common-ball valve, which carries it to *g*, where the product is to be subsequently handled.

This pump permits the residuum to be carried 270 meters without the least difficulty. A special arrangement allows the cossettes to be pressed before they leave the circulating pipe. Under these conditions 50 to 60 per cent of their water is eliminated. These pumps must be very strongly constructed, as considerable interior

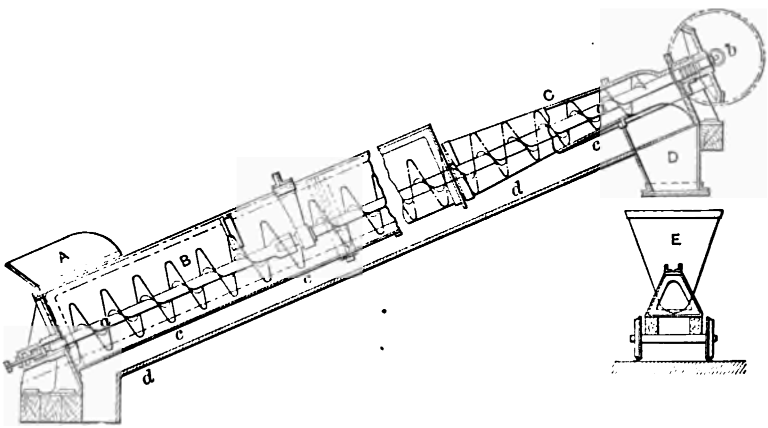



FIG. 141.—SKODA Cossette Press and Carrier.

pressure is sometimes exerted, owing to the fact that portions of the residuum pack into one solid mass, which must be rapidly carried from the battery to the receiving station.* This cossette pump appears to be simply a modification of the BLANCKE † press constructed over twenty years ago.

**Distribution of the cossettes.**—Upon leaving the carrier the cossettes fall into a hopper connected with the residuum cossette presses. As these presses only work as they should when well filled with residuum cossettes it is necessary that the product be supplied to the apparatus with great regularity. Whatever be the type of presses used they may be arranged in battery, so to speak, the cossette distribution or filling being accomplished by a spiral device. As a hopper connects the carrier with the presses these are

* D Z. I., **26**, 453, 1901. † La. S. B., **10**, 165, 1881.

all kept filled, and it is only the last press that does not work satisfactorily.

**The presses** now generally used are of the KLUSEMANN or the SELWIG and LANGE types, the KLUSEMANN press being the outcome of SCHLICKEYSEN's suggestion. A section of the KLUSEMANN press is shown in Fig. 143; in many respects it is one of the best known. This machine does not extract the water as completely as the hy-

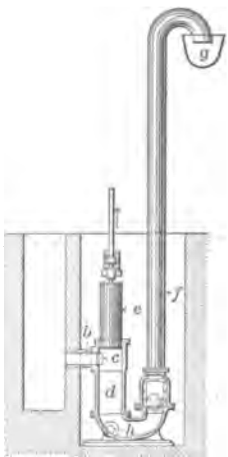



FIG. 142.—LIMPRICHT Cossette Pump.

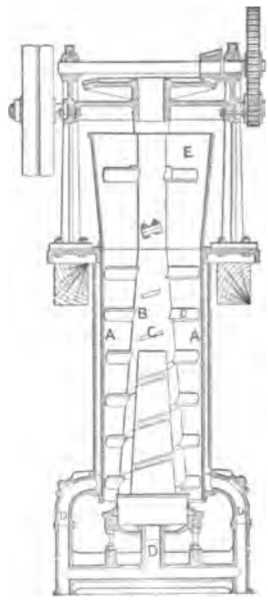



FIG. 143. — KLUSEMANN Cossette Press.

draulic press, but it does, working continuously, deliver a pressed mass with 12 to 14 per cent of dry substance almost equal in value for cattle fodder to ordinary beets. The idea of KLUSEMANN's press evidently came from the clay-mixing machine, which has been used with so much success for mixing pressed clay with water. Here, as in the clay-mixer, the mass is worked by knives and screw-formed cutters, and at the same time is forced through a very contracted opening. In the KLUSEMANN press this is effected by a perforated cone *B*, which works in a perforated cylinder and is furnished with iron or steel blades *C* placed in screw form. These blades seize and force down the cossettes which are fed in at the top, and as the cone expands at

the bottom and the cylinder is of equal diameter throughout it is evident that a strong pressure must be applied to the cossettes as they approach the contracted opening between the cone and the cylinder at the bottom.

The water pressed out escapes through the perforations of *A* and of the hollow cone *B*, and passes through the three tubes *D*, which distribute it in the direction desired.

The speed must be so regulated that the elevator will bring just enough material to keep the hopper *E* constantly full; and it is thought desirable, when the cossettes are not in sufficient volume to fill the same, to stop the machine, as otherwise inferior results will be obtained. The machine should always be started slowly and when entirely filled run at a regular rate of 3 to 5 revolutions per minute, regulating the elevator accordingly. The motion is given by a pulley carrying a pinion which works in a cog-wheel. This is keyed on a horizontal shaft the latter having also a beveled pinion which works in a beveled cog-wheel, fastened on the prolongation of the upper axis of the cone just above the box in which the axis turns. The lower axis *D* is hollow to allow the liquid inside the cone to escape. Upon the inferior part of the cone slides a conical obturator provided with strong set screws, by which the obturator can be raised or lowered, to lessen or increase the size of the opening of delivery and the consequent pressure, as may be desired.

It is not possible to convey the cossettes by a moving apron direct from the bottom of the diffusion battery to the hopper *E*. But they are emptied from the lift into an Arçhimedean screw that carries them to the presses. An advantage of this press is that it requires no care and little or no attention. Fifty tons of cossettes may be worked in twenty-four hours through one press of this description. This amount may be augmented by increasing the diameter of the apparatus. The force required is said to be about 1½ H.P. According to Nobel * the average composition of the pressed cossettes from the Klusemann is given in the following table.

Among the important improvements made in these pulp presses may be mentioned the Neumann † arrangement, in which a series of conical rings, exterior to the perforated outer casting, force the water from the perforated sheet iron to circulate along its edge

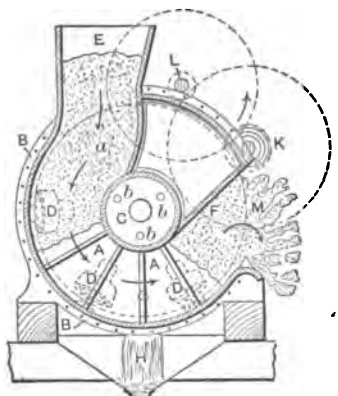
* Z., **26**, 1048, 1876. † Z., **53**, 98, 1903.

| Constituents of | Exhausted Pressed Cossettes. | Sweet Water. | | |
|---|---|---|---|---|
| Water | 87.238% | Ash | 1.181 | 7.54 per cent dry substance. |
| Raw protein | 1.537 | Saccharose | 2.349 | |
| Fatty substances | 0.025 | Dextrose | 0.010 | |
| Non-nitrogenous substances | 8.076 | Protein | 1.984 | |
| Cellulose | 2.310 | Cellulose | 1.132 | |
| Ash | 0.814 | | | |

and thus prevent any reabsorption by the cossettes. The exterior casing is wider at the bottom which obviates clogging between the rings and its surface.

The SELWIG and LANGE presses work upon an entirely different principle. This press, which is shown in Figs. 144 and 145, operates in the following manner:

The hopper *E* receives the cossettes, falling at *a*, between disks which form a wedge-shaped chamber, whose walls continually




Transverse Section.
FIG. 144.

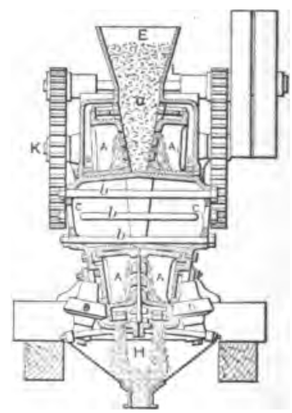



FIG. 145.

SELWIG and LANGE Cossette Presses.

move towards the smallest space, and are carried around by the friction and rotation of the disks. As the latter gradually approach the narrowest portion of the space *a* at the lower part of the press, the narrowing disks exert a most powerful pressure on the cossettes, while the liquid contained in the latter passes through the perforated surfaces of the pressing disks. The pressed cossettes passing the narrowest portion—after which the distance between the disk surfaces again widens—are forced by the follow-

ing mass against the fast scraper $F$ out through the opening $M$ in the jacket and form a tolerably consistent mass. The pressed-out water flows through larger openings in the jacket into a drain $H$.

The degree of pressure on the cossette, which is in proportion to the distances between the disk surfaces, can be altered by changing the press disks $A$, $A_1$, moved on the axis $CC_1$ by set screws provided for that purpose.

The press is driven by fast and loose pulleys on the shaft $L$, turning a pinion which works into the cog-wheel $K$. As soon as the cossettes in hopper $E$ begin to give out the press should be put to work; for if it be not sufficiently filled the pressing will not be so well done. It is important that all the shafts and the cog-wheels be kept well oiled.

The cone cossette press may be placed either on the surface of the ground or over rooms to be used for other purposes, provided the liquid can be carried off properly. Since the machine has no separated parts, and the pressed cossettes fall from it at the height of 1 meter, a transporter running underneath may be filled and carry the cossettes to another place.

In most cases it would be best, especially if KLUSEMANN'S press is to be used, to arrange this press directly under the cossette elevator in the story over the cossette storage-room. When there is sufficient height for the elevator above, the presses can be thus conveniently located.

In new factories, or in those being altered, it is better not to place the press in a separate building, which is usually colder, since experience proves that the cossettes may be pressed to much greater advantage in a warm place. In such a case the pressed cossettes can be carried by a wheeled transporter, an endless screw, a link belt, or some other arrangement, into the cossette store-room, and the building need not be more than two stories in height.

It is essential that these presses be run with regularity and kept constantly filled with cossettes. As long as they are full the cossettes are submitted to a normal pressure against the sides of the apparatus, but as soon as the supply of the residuum decreases, which frequently occurs during irregular working and the subsequent emptying of the diffusors, the residuum is not pressed and leaves the presses in a moist condition. Experience shows that it is preferable to supply the cossettes to one press after another from one end of the series than to feed from the center of the

series, there being thus a greater chance of a greater number of presses working continuously. If the feeding of the hopper *E* is not continued with great regularity there will be periods when it will be only half full, in which case no actual pressure is exerted.*

One hundred kilos of fresh residuum from the battery give 47.17 kilos of pressed cossette and 52.83 per cent of sweet water. For every 100 kilos of pressed cossette there is lost about 0.84 kilo of dry substances.† Opinions differ as to the necessity of excessive pressing, but it is now well established that the quantity of broken particles of pulp passing into the sweet water increase with the pressure exerted. CLAASSEN says that if one wishes to keep this residuum, or to use it for feed, it is not desirable to push the pressure beyond a certain limit, so that it contains, for example, 10 per cent of dry substance. If, on the other hand, the cossettes are to be dried, which is frequently done, a decrease in the percentage of dry matter and fuel economy must be considered. Consequently it is rational, with the existing high price of fuel, to push the pressure to such a degree that the product will contain as much dry substance as possible and the least water.

An astonishing fact, which is not generally appreciated, is that the suspended pulp carried off by the water pressed from the residuum cossettes for a factory working 16,000 tons per campaign, represents a money value of $240, making allowance for the fact that the pulp may be sold to farmers for $1.20 per ton. Consequently it is recommended that this water be strained or sent into decanting vats in order that the floating organic matter may be separated before it is allowed to run into the river.

**Losses during pressing.**—Experts do not agree as to the actual loss during pressing. According to BARTZ, there is a loss of about 0.28 per cent of the proteid substances passing out in the sweet water of the cossette presses when one obtains 50 per cent of pressed cossettes for the total weight of the beets worked, which is about an average.

On the other hand, STAMMER declares that this loss is very much greater, and when the weight of cossettes is reduced to 38 per cent there is a consequent loss of 5.5 per cent of dry substances in the sweet water forced out from the residuum.

CLAASSEN has also found that the loss is considerable. He has pointed out that even with a slight pressure the losses of nitro-

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* Z., **29**, 1180, 1879.

† Z., **26**, 1048, 1876.

genous substances reach 7 per cent and of non-nitrogenous 9 per cent. On the other hand, by excessive pressure the loss is 10 per cent of nitrogenous and 15.04 of the non-nitrogenous substances. He, therefore, justly finds that these are no longer insignificant quantities that may be overlooked.

The essential reason for this diversity of data may be found in the composition of the cossettes submitted to pressure, as the more complete their exhaustion during diffusion the less will be the loss of dry substance during subsequent preparation. The experiments of HERZFELD have demonstrated that unless the residuary cossettes contain an abnormal percentage of sugar the losses are not much higher with excessive pressure than they are when the product is only moderately pressed.

One of the chief objections to an abnormal pressure is the slowness of the operation, which, for existing sugar plants, throws out of gear the successive operations of sugar extractions. Furthermore, the early experiments of MAERCKER * show that the results obtained would hardly be in proportion to the increased expenditure of power. In his experiments different cossettes were submitted to a pressure of 300 atmospheres, and yet the pressed cossettes contained only from 17.7 to 18.62 per cent of dry substances. The higher the percentage of sugar of the residuary cossette the greater will be the ultimate loss in the sweet water. To the pressed residuum may be added the tip ends of beets, etc., separated from the residuary wash water. BEAUVAIS sends this residuum into the exhausted cossette flumes, from which it is raised into the presses. This in no way destroys the keeping powers of the product and has the advantage of furnishing 1 to 1½ per cent of additional residuum. Some authorities maintain that this plan should not be adopted, for the reason that the tip ends and broken portions of beets frequently contain considerable sugar which will readily ferment and form a nucleus of infection. The fact is that all siloed cossettes ferment during keeping, and this is accompained by an increased temperature in the mass. WEIS † found that sour diffusion cossettes contain a special bacteria to which he gave the name of *Bacterium pobuli acidi* I, II and III; but no bacteria explaining the formation of acetic acid were discovered. For the production of this acid air is needed, while the *Bacterium pobuli* may develop at the expense of the sugar and the albuminoids contained in the

* Z., **35**, 229, 1885. † Bl., **6**, 287, 1899.

residuum. The transformations that occur are about as follows: First are formed the fixed and volatile acids, lactic, acetic, butyric and formic, the latter in very small quantities. Later lactic acid disappears and the acetic acid is present in excess.*

**Methods to facilitate pressing.**—The construction of the presses is not the only question to be considered as the nature of the residuum also has an actual influence. For example, when the exhausted cossettes are thin, they will be better pressed than when large and hollow, and when the residuum is run from the diffusors rather hot the pressing is always more satisfactory than when cold. On this point HERZFELD'S † experiments bring to light some important facts. He concludes that the best results are realized when the product in the presses is at 60° C. Too high a working temperature of the battery will cause undesirable losses of nutritive substances during pressing. The loss of albumin under normal conditions may reach 2.9 per cent, while when abnormal methods are adopted the sweet waters may contain 11 per cent of the albumin of the exhausted slices.

CLAASSEN says that this mode of working is not to be recommended when it is desired to keep the residuum in silos; for besides the loss of nutritive substances through pressure hot cossettes ferment rapidly even after a few hours, and their keeping powers are inferior to those of the residuum that has been pressed cold and ferments normally.

The theory of the MANOURY method is based upon the simultaneous action of heat and a suitable chemical, which coagulates the albuminoids in the tissues of the beet. Its application to diffusion consists in adding lime to fresh beet cossettes during the diffusion at 70° C., allowing the contact to last for at least 20 minutes. The cossettes subsequently give excellent results by pressure.

The lime may be mixed with the cossettes in many ways. The weak juices running from the diffusion battery are used again instead of water for the general working of the battery. The advantages of such a practice are as follows: 1. A considerable diminution of the quantity of water required for diffusion. 2. The saving of 0.3 to 0.4 per cent of sugar, which is frequently lost in the refuse water and cossettes. It is said that juices extracted by this method are at least as pure as those from the first carbonatation, and consequently the latter operation may be effected with 1 per cent of

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* S. I., 54, 549, 1899. † D. Z. I., 27, 1103, 1902

lime, giving a purity equal to that obtained with 3 per cent by the customary process. It is estimated that by an additional expense of $1600 there would result an advantage of $1.40 per ton of beets and for an ordinary campaign a saving of over $12,000. These figures, if correct, are of sufficient importance to warrant their careful examination by every beet-sugar manufacturer.

BOSSE * favors the use of hot alkaline water which is said to have all the advantages and none of the disadvantages of liming. The water used for this purpose is the ammoniacal water from the multiple effect. The method is favored in case the cossettes are to be dried at once, for their keeping powers decrease, although this statement is challenged by PFEIFFER, who says that the reverse is true.

SCHEERMESSER uses in the last diffusor of a battery water that is saturated with anhydrous sulphurous acid. The resulting residuum is then easily pressed, and the albuminoids are coagulated, under which conditions they will be retained in the pressed cossettes and will not pass off in the sweet waters. When the product is dried and left in the air for a certain time the anhydrous sulphurous acid seems to evaporate, but it remains to be proved whether the product could be advantageously fed to cattle.

MAERCKER,† after a long series of laboratory investigations, concluded that when exhausted slices are mixed with lime or alkaline salts, the cellular tissues of the product became very much more porous. The most efficacious method is the least expensive. It consists in submitting the cossettes to the action of 0.5 per cent of lime, using it in the form of milk of lime. The receptacle in which this mixing is done has a suitably arranged agitator which produces a perfectly homogeneous mass. This operation lasts from 20 to 30 minutes, and the product thus obtained gives up a large percentage of water under the slightest pressure. Some investigators, who have used the milk of lime treatment, claim that the dry substances in the final pressed product reach nearly 30 per cent (?), that the limed cossettes are possessed of an agreeable flavor, etc.

SIEKEL also recommends this mode of working, but under no circumstances should the residuum be allowed to be in contact with the lime for more than 30 minutes, as otherwise the physical condition of the product would be altered, and it would then, in a measure, be worthless for the purposes intended. The residuum

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* C., 8, 144, 1899.

† Oe.-U Z., 14, 33, 1885.

would be transformed in the presses into a compact mass, which could not be compressed without breaking the press, and it would be necessary to cut the mass into pieces in order to remove it.

Mueller proposes the washing of the cossettes in lime water before pressing. Under this treatment the residuum increases in the value as a fodder, and the lime will later on constitute an obstacle to the excessive fermentation in silos, which is always to be dreaded.

**Residuum cossette loft.**—The cossette presses are generally placed at a considerable elevation so that the product after pressing may readily fall into the cossette loft, underneath which the carts and cars may freely circulate. As a general thing a spiral carrier underneath the cossette presses conveys the pressed residuum to the exterior or to the boats or cars. A small reserve is frequently kept in the lofts, the quantity depending upon the strength of the floor girders. It is said that a cubic meter of the pressed cossettes weighs 500 to 600 kilos, after keeping 800 to 900 kilos, while from the dryer the weight is only 220 kilos per cubic meter.

**Transportation of the cossettes to silos.**—The best way to transport cossettes to the silos is by the use of Decauville cars which enter the factory on a trestle and are subsequently emptied over the silos. For the same purpose long spirals, overhead wires and trolleys are also used.

**Siloing the pressed cossettes.**—Strange as it may seem less and less care is taken in siloing the residuum. Some factories simply empty the product into ditches, allowing the upper surface to rot and form a protective layer for the product beneath. This covering is from 10 to 15 cm. in thickness and may be readily removed. The ditches are paved with stones.

When building a silo the very best material should be used, and as there is considerable lateral and vertical pressure the side-walls should be sufficiently thick to offer the desired resistance. The corners should be filled in with triangular or rounded bricks. For many years it was argued that diffusion pulps could not be kept in silos lined with bricks, but experiments have shown such theories to be erroneous. Cossettes remaining for five months in silos thus constructed lost only 8.9 per cent of their dry substances.

It is customary to pile the residuum cossettes in carefully constructed ditches lined or not with masonry and cement. There are advantages especially to be derived by the use of elongated silos, so that the portion exposed to the air during their opening

shall be as small as possible in order to reduce to a minimum the amount which will subsequently rot through oxidation. The dimensions, length, depth, etc., recommended by various recognized experts, are extremely variable. As the most desirable types of silos for residuum beet pulps are expensive, they are not within the reach of the average farmer. When beyond a certain size they must be cement lined.

Pellet and Lelavandier recommend that the length be 25 meters, width 4 meters and the depth about 1½ meters. These dimensions vary with the conditions one may have to meet. There are no objections to greater depths, provided the soil is not damp. It is not desirable to reach a depth where substrata water currents may be met. Other dimensions that may be brought forward are based mainly upon the various conditions that different environments create. It is very rare, however, for the depth of silos to exceed 2 meters. Sometimes very deep silos, 3 meters, give good results, as the pulp then eliminates considerable water by its own weight.

Sometimes the size is regulated so that a wagon may turn upon itself in the silo, which calls for a width of at least 5 meters. The width of the silo must vary with circumstances. If too great, its covering would offer some difficulty; but it should never be less than that of an average cart.

It is recommended that the bottom of the silos be paved in such a way that there shall be a slant of 15 or 20 millimeters per meter from the entrance to the exit, to facilitate the flow of water from the cossettes. In certain cases it has been found that this slant should be double, thus permitting the flow from the right as well as the left. Under these circumstances there is no deposit of water at the bottom of the silo and stagnant water of any kind would soon contaminate the mass of the residuum. Sometimes it has been found of advantage to draw off the water; filtration has also been proposed by allowing the water to collect in special wells, filled with stones or other material, from which, when the occasion presents itself, it may be pumped out. Some experts advocate the building of silos on porous soil.

The bottom paving of a silo materially helps the conservation of the siloed cossettes, and experience has shown that for a silo of average dimensions all lateral walls, whether of brick or other material, are unnecessary, as they render only a very slight service especially in plastic soils.

HERZFELD says that the slope of the silos is of secondary importance, and that the transformations which occur depend mainly upon the degree of dryness of the product upon leaving the presses.

It has frequently been found that certain economical advantages may be derived by the introduction of small cars, of the DECAUVILLE type for example, travelling on narrow gauge tracks on the upper level of the silos. This arrangement allows the residuum cossettes to be carried rapidly and under very economical conditions from the factory to the ditch or silo in which they are to be kept.

Silos should be filled during cold weather and the operation should not last more than three days. In our climate the beet-sugar campaign frequently commences before frost sets in, so that the operation would take place at the wrong period. It would be better at first to feed direct to cattle. Farmers should not forget that siloing during warm weather means very inferior fodder later in the season. In order to have the mass of pulp perfectly uniform, and to prevent air from being imprisoned, as its influence is very destructive, it may be compressed as much as possible, with the back of the spade or other flat instrument used in filling. Tramping upon the residuum by walking a horse or cow over the product during filling is a very common custom, and covering the bottom of the silo with several inches of chopped straw is a good practice, the advantages of which are numerous. Alternate layers of pulp and straw are to be recommended only in certain cases. The writer is rather in favor of alternate layers of salt and residuum. One man's labor for filling and emptying a silo of 5-ton capacity is sufficient.

Silos are generally open on top. Experience has shown, however, that advantages are to be derived from resorting to a covering of at least two feet of earth, in order to prevent the action of air and putrefaction. When crevices open, due to the settling of the mass, they should be closed as soon as possible.

The cossettes are placed in silos so that the top is about two feet above ground which materially contributes towards pressing the mass of matter beneath. The sides above ground should slant and be gradually covered with earth, the latter being beaten down with care. After an interval of several days, this outer covering being well settled, another layer of clay is added under the same conditions.

Various coverings for the top have been suggested, such as defecated scums, ashes, etc., but earth seems to be the best of all.

If proper attention is not given to the question of covering, putrefaction will spread from the surface to a depth of two feet during a severe winter; while if properly covered, the pulp may be found in an excellent condition two inches from the surface. Is is to be regretted that some of our farmers use straw which is the very worst material that could be selected for the purpose. Heavy weights on the top have some advantage, but the best of all, as before stated, is earth which may be several feet in thickness, and its weight upon the pulp will be all that is desired.

Experience has shown that when the silos slant from bottom to top, considerable advantages are found as far as the keeping qualities of the residuum are concerned. Silos when filled settle about 10 per cent, and it is to be noted that the settling is of considerable importance, for the simple reason that if the volume of the product before and after siloing is known one can economize on the cubical contents of the silos.

It is very advisable in order to obtain the best results in cossette keeping, especially during the period when they are withdrawn from the silos, to sub-divide the various chambers in which the product is kept into several compartments. These separations are made at different points in the direction of the least dimension by suitable walls of stone or earth, in such a way that even when one of these divisions is entirely open it in no way interferes with the adjoining one. Under these circumstances it is possible to arrange so that the supply for the day may be sufficient to meet any possible emergency, and in no way have an influence, as far as atmospheric action is concerned, upon the product being kept in the adjoining section.

**Transformation during siloing.**—If one leaves fresh cossettes exposed to the air there follows a putrefaction after a very short time. Notwithstanding this fact, very often when the factory method of working does not allow the construction of any special silos, and when the farmers refuse to undertake it, the product is simply thrown in piles and left exposed to the air. Under these conditions it becomes evident that the factories must lose by sacrificing a product which enters very materially into the financial profits of the season when the entire bulk of the sugar campaign is considered, and this under better management would be unnecessary.

This organic transformation, or putrefaction, even during siloing, may represent a sacrifice of 30 to 50 cms. in depth taken from the surface or a considerable proportion of the total product.

It becomes evident that the essentials for the proper preservation of these cossettes are to keep out the air and rain. The destructive action of rain and air increases with the time of storage, for the reason that the cells of the residuum thus kept open more and more, and the rain entering carries away a large percentage of the nourishing elements.

Do what one may, numerous transformations always occur in the silos; there arises in the mass a fermentation of all, or nearly all, of the organic substances, such as the non-nitrogenous, which are partly converted into lactic acid. Under these circumstances the cossettes are possessed of a decidedly acid reaction and may contain, according to MORGEN, more than 4.7 per cent of their dry substances as organic acids, calculated upon a basis of lactic acid. This apparently abnormal quantity has very much less influence on the digestion of animals than might be supposed. It gives, on the contrary, a rather agreeable characteristic sour taste, to which cattle soon become accustomed and eat the product with great avidity.

But, it is to be noted, that for the cossettes to undergo this lactic fermentation to the best advantage, they should reach a temperature of very nearly 40° C. without any supplementary heat other than that found in the siloed mass, otherwise there will follow an objectionable acid fermentation, under which circumstances, instead of lactic acid, a micro-organism known as mycoderma aceti soon shows its activity, resulting in the formation of acetic acid, for which live stock in general have a distaste. Certain cattle absolutely refuse it under any and every circumstance, and the product then has absolutely no commercial or feeding value.

As the temperature in the silos is quite high it should be measured with a thermometer and controlled. Experiments have been made to collect some data as the silos filled with two kinds of pulp, and the difference in heat evolved after some time was remarkable. A comparatively high temperature is generally desirable, for the reason that it shows that fermentation has commenced.

The principal centres for change in silos are along the sides and in corners, and no well-built silo should have angular corners as a thorough cleaning when emptied would then be impossible. The shape of a silo has consequently an important influence upon the keeping of the cossettes. Most experts say that the sides should be vertical, so that there will be a regular pressure of the pulp by its own weight. The writer much doubts if vertical sides accomplish all that is desired; an inverted truncated pyramid would

be better. No experiments have been made in this direction, so it should not be practically tried unless there be in advance some certainty as to results.

According to LIEBSCHER, fermentation diminishes after the sixth day of siloing, and when the fifteenth day is reached the temperature of the mass undergoes little or no change, and is about the same as that of the ground in which the ditch has been made. These transformations, as regards the chemical composition of the products, are shown in the table which follows, as given by MAERCKER:

EARLY CHEMICAL CHANGES DURING SILOING (MAERCKER).

| Constituents. | Fresh Pressed Cossettes. | Dry Matter. | Soured Cossettes. | Dry Matter. |
|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Water | 89.77 | ...... | 88.52 | |
| Dry matter | 10.23 | 100.00 | 11.48 | 100.00 |
| Ash | 0.58 | 5.67 | 1.09 | 9.05 |
| Fatty substances | 0.05 | 0.49 | 0.11 | 0.95 |
| Cellulose | 2.39 | 23.36 | 2.08 | 24.39 |
| Nitrogenous substances | 6.32 | 61.78 | 6.41 | 55.84 |

From this data one may conclude that during the keeping of the residuum its percentage of dry substances, such as ash, fatty constituents, cellulose and nitrogenous elements, is materially increased. While this is true of the fatty constituents (it is to be noticed that albuminoids under certain conditions give fatty constituents through decomposition), the phenomenon is very misleading as far as the other compounds are concerned, for the simple reason that the water percentage has been lessened, and there is consequently a corresponding increase in the dry substances. It is well to understand that there has not been a corresponding loss of the dry constituents, for whatever may be the loss of these it is never proportional to the losses of watery vapor, whatever they may be. While the loss of water may be 40 per cent, it does not necessarily carry with it 40 per cent of different compounds forming the actual constituents of the cossettes proper, which fact may be noticed by the relatively increased nutritive value of the material. The fact is, that the actual analysis of soured cossettes shows the material advantage of submitting the fresh product of some siloing. Gradually, as the period of their keeping progresses, this phenomenon, or transformation, so to speak, becomes more

and more pronounced, as the analysis of PETERMANN evidently proved.

CHEMICAL CHANGES DURING PROLONGED SILOING (PETERMANN).

| Constituents. | Cossettes after 8 Months' Keeping. | Dry Matter. | Cossettes after 2 Years' Keeping. | Dry Matter. |
|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Water | 87.08 | ...... | 83.98 | |
| Dry matter | 12.02 | 100.00 | 16.02 | 100.00 |
| Ash | 1.02 | 8.36 | 2.96 | 18.48 |
| Fatty substances | 0.08 | 0.65 | 0.74 | 4.62 |
| Cellulose | 2.67 | 21.89 | 5.06 | 31.59 |
| Albuminoids | 1.00 | 8.02 | 1.83 | 11.42 |
| Organic nitrogen | 0.16 | ...... | 0.29 | |
| Carbohydrates | 7.43 | 60.09 | 5.43 | 33.89 |

Unfortunately the keeping in silos of a product such as this necessarily means a considerable loss, which in some cases amount to from 40 to 45 per cent, and one must make the best of these conditions.

**Surface siloing.**—It may be admitted upon general principles that the cossette residuums will keep well provided the water they contain can drain off, and the product is well protected from the rain and variations of the exterior air. A very simple arrangement for surface siloing is shown in Fig. 146. On each side of the


FIG. 146.—Surface Siloing.

pile are suitable ditches that carry off the dripping water from the moist pulp; the earth covering is taken from the ditches. *A* and *B* represent layers of straw projecting beyond the sides, which act as drains from the interior.

A wood-built silo used in France is shown in Fig. 147. Just within what limits this style is suitable to our cold climate experiments alone can determine; for California, however, it would be excellent. Silos of this type are 25 to 30 meters long by 4 to 5 meters wide and 1 meter in height. The bottom is made of stones

placed on end, with sufficient grade to carry off the water from the mass of pulp into lateral drains communicating with a special manure pit. Wooden posts, 20 cm. square, penetrating the ground at least 80 cm., are placed vertically at intervals of 2 meters and are held in position horizontally by iron bars 12 mm. in diameter, which overcome any lateral pressure.

The sides of the silo consist of boards 30×2.5 cm. with a space of 2.5 cm. between each, and all should have a thick coating of tar. To facilitate filling and assure keeping the mass in good condition,

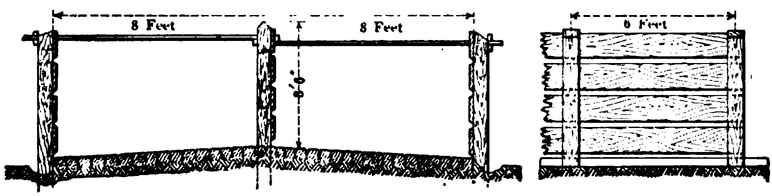



FIG. 147.—Surface-built Silos for Beet Pulp as used in France.

the silo is divided into two parts by a partition of posts and boards. The silo may be filled by means of a wheelbarrow from a plank slanting up from the ground. The iron braces are placed in position gradually during filling, and withdrawn as the silo is emptied. The capacity of a silo of this type is 300 tons.

**Concluding remarks respecting cossette residuum.**—Most farmers in continental Europe, when contracting to grow beets for the sugar factories, stipulate in advance that they must receive cossettes weighing at least 50 per cent as much as the beets furnished. Under these circumstances it is to the manufacturer's interest to obtain the largest possible quantity of residuum cossettes. Unfortunately, very dishonest methods are frequently employed to this end, and the manufacturer gains nothing by submitting the cossettes to an excessive pressure.

It would be to the interest of the tiller to stipulate in his contract that the residuum shall contain a certain quantity of dry matter. If this is less than 8 per cent the product should be refused. As affairs now stand the farmer frequently receives water instead of the valuable constituents expected, and derives no benefit from the product. Then, too, when the water has not been removed the mass of cossettes has considerable weight and the cost of its transportation is considerably higher than it should be. Furthermore, the nutrients contained in the product are frequently

so diluted that they have a pernicious effect upon the health of the animals being fed.

The market value of residuum cossettes from sugar factories depends upon many conditions—their composition, the manner in which they are obtained, the abundance of other crops, and the distance from factory to farm. In most European countries contracts for beets are made between farmer and manufacturer at $4.00 per ton, the farmer reserving the privilege of purchasing the residuum pulp at $1.00 to $2.00 per ton, in quantities corresponding to one-fifth of the weight of beets furnished. When pulps are delivered at farms allowance is made for such transportation. Considerable change occurs in the composition of the product during transit. The percentage of water increases the cost; for example, if 80 carts are required to carry a given weight of pulp containing 80 per cent water, 85 carts would be necessary for transporting the same pulp if the water percentage were 85 per cent.

By means of oxen the cost of transportation of pulp to a farm at average distance from the factory is 15 cents per ton. This price permits keeping oxen, or other animals used, in good condition, and in a few years pays their value. Difficulties constantly arise between manufacturer and farmer; either the latter wants more than his contract calls for, or he maintains that the refuse is inferior in quality to the product formerly used. As the percentage of cossettes obtained varies with the saccharine quality of the beets worked, it is not well for the manufacturer to make any rash promises as to the amount he can furnish and the quality of the product. Hence 20 per cent is considered a reasonable limit. From 100 kilos of beets there are obtained on an average 42 kilos of cossettes; the difference should be consumed by animals at the factory.

If the diffusion is not conducted under the most scientific principles, the feeding value of the pulp suffers. If the temperature is too high, there follows a coagulation of many of the nutritive elements. To protect the farmers' interest and to make sure of harmony among those interested, an understanding should exist as to the limits of temperature at which the battery is to be worked. If farmers sell siloed pulp to their neighbors they should ask double the purchase price at the factory, to which should also be added the expense of transportation and siloing. The bulk is reduced one-half, but the value has remained unchanged.

These pressed cossettes are in some cases fed to live stock as fast as received or they may be kept in specially built silos. Farmers collect the product at the factory in wagons or carts, or transport it by water in boats constructed for this purpose.

The best arranged factories generally have a number of oxen to feed, and it is well to have a certain amount of diffusion cossettes placed in silos at the factory for the purpose. These silos are usually of the very best types.

**Cossette drying—General remarks.**—The feeding, keeping, handling, etc., of fresh or siloed cossettes for a forage entail certain complications, and there must necessarily, therefore, be some advantage in drying them.

The first really serious experiments made in this direction were those of Blossfeld in 1878, who at that period had conducted quite a propaganda for the encouragement of the idea of cossette drying which he had been expounding, and the necessity of discovering some practical means for overcoming the many difficulties involved. The idea was not well understood by the German farmers and sugar manufacturers until 1883, when a prize of 15,000 marks ($3750) for some practical solution of the question was offered. In order to make the matter thoroughly clear to those interested in the subject certain conditions were stipulated, viz.: The dried pulp should contain only 14 per cent water, about the same as hay; it should be without any perceptible odor, and not burnt during drying; the loss of nutritive elements should not be more than 8 per cent; the expense must not be more than about 5 cents per 100 kilos of pressed cossettes used.

Buettner and Meyer were awarded this prize, and their apparatus, which is actually of great practical value, was the starting point for the realization of an idea that has since been of considerable importance to the feeders of beet-cossette residuum the world over.

It is interesting to note the farmers' assertions that it was paradoxical to state that a handful of the dry product could have the same nutritive value as a bucketful of the moist substance from which it was made. These arguments occasioned numerous agricultural gatherings at which the entire question was discussed upon a very practical basis. The rural press of the country took up the question and the actual outcome has been that dried cossettes are now considered a staple commodity upon the German market.

To MAERCKER and MORGEN is justly due the credit of having confuted, through their numerous publications, all the erroneous arguments of many of the would-be scientists who attempted to cry down this valuable product.

Before describing exactly the practical solution of cossette drying, it is important to insist upon the necessity of the dryers producing an initial product which shall contain the greatest possible proportion of dry substances; and from this standpoint one may notice that since these desiccating appliances were first introduced, the percentage of dry matter contained in the pressed cossettes has risen from 12 per cent to 16 per cent, which means that there is 30 per cent less water to be evaporated than formerly, this phase of the question representing a great fuel economy.

**Liming before drying.**—BUETTNER and MEYER some years since forced the cossettes through perforated cylinders combined with a slanting spiral arrangement which was in close communication with another receptacle containing milk of lime, in which the residuum became saturated with lime. It was subsequently strained before leaving the upper parts of the cylinder.

Without doubt, lime has great influence upon the cellular texture of the beet slices being treated, and will often permit a greater percentage of water to escape; but independent of certain mechanical complications that need not be mentioned here, there is always danger of hardening the cossettes. It frequently happens that the fuel used for the drying in this appliance contains sulphur. The gases of the furnaces will then be saturated with anhydrous sulphurous acid, which, coming in contact with the lime of the cossettes during their working in the BUETTNER and MEYER dryer, would result in a calcic deposit.

HERZFELD called attention to the fact that after a reasonable period of storage, this dry residuum threw out sulphuretted hydrogen, notwithstanding the fact that it contained almost insignificant traces of this chemical. At the present time liming of residuum cossettes has been practically abandoned, and there remains now only the natural, dry cossettes, which are becoming yearly more and more popular.

The drying of cossettes is an important subject into the consideration of which numerous factors enter. No general rule can be given. In most factories the local conditions are not considered favorable to this process, and only a comparatively few have introduced the dryers. These installations increase the cost of the

general plant of the sugar factory, and do not always give the manufacturer a compensating return on the investment. All facts considered, it is the farmer who derives the actual advantage, and unless he appreciates the difference between the dried and moist residuum, there is no possible reason why the dryers should be built. However, if a factory is unable to dispose of its fresh residuum cossettes to neighboring farmers, it is an actual advantage to the manufacturer to have a drying plant. For the desiccation of pressed cossettes a furnace or a drum may be used in which the drying may be done by two methods—either directly, using the gases of combustion, or by indirect methods, which, however, are more expensive without a proportionate increased efficiency.

**Waste gases for drying.**—Drying might be most economically accomplished by using the gases escaping from the grates of the boilers, which combine with the gases in the special generators. It is maintained that there is thus produced an intense gas circulation, which is very favorable to the residuum desiccation, without danger of cooling or any loss of heat. Furthermore, it is stated that during this special drying the cossettes will not absorb any of the gas combination, as the water they contain must increase 1700 times in volume before becoming steam, and under these circumstances there is created a current of vapor sufficiently violent to prevent any direct contact between the cossettes and the gas proper.

Experiments have shown that to properly utilize this lost heat from the boilers would necessitate the building of a very large and expensive appliance. Furthermore, steam boilers are rarely arranged as they should be, and an enormous amount of gases is always liberated from them which cannot be utilized, as it is unfortunately supersaturated with soot, and the working of the boilers, too, is very irregular.

The construction of a special furnace for accomplishing the object in view is the main point on which attention should be centered. It has been found desirable to obviate the contact of the gases with the residuum cossettes, in order to prevent their contamination. None of the combinations thus far devised are very serviceable in their general working, from an economical standpoint, for the simple reason that there is always an enormous loss of heat through radiation.

**Utilization of lost heat for drying.**—It has frequently been suggested that for the drying of cossettes the lost heat from the various appliances of the factory should be used. Investigations

in this direction have been centered upon the utilization of the latent heat of the exhausted cossettes, but up to the present time the results obtained have been by no means encouraging.

Many experts have tried to utilize the latent heat of evaporation, because they believed that in order to evaporate the water of the heated cossettes in the furnace it was sufficient to circulate air in the dryer, which, owing to its natural hygroscopic power, would become supercharged with the watery vapor. A fact which has been apparently overlooked is that a realization of this method would necessitate a supplementary expenditure of caloric for heating of the air used in the dryer. Finally, experiments were made to utilize the heat contained in the water evaporated, in the same way as in such evaporating appliances as the triple and multiple effects used in the sugar factories. The substance here dealt with is, however, not so fluid as beet juice. All facts considered it is difficult to arrange an apparatus, or combination of appliances, that would meet the numerous demands of beet-cossette drying. The transferring of the cossettes from one receptacle to another cannot be accomplished with the same ease as when handling liquids. In order to overcome this difficulty it has been proposed to reduce cossettes to a sort of paste. Furthermore, the cossettes have not the same contact with the heating surface of the evaporator as is possessed by liquids, and the coefficient of heat transmission falls very low. The multiple effect mode of desiccation would demand appliances of stupendous size.

All efforts to apply the rational principles of economy in the operation of cossette drying have failed, and, strange as it may seem, the most irrational apparatus yet devised has apparently led to the most practical results. The rational application of heat, based upon the principle of counter currents, in which the cossettes come in contact with gases of an increasing temperature, was not successful, because the residuum was simply burned. The inventions to overcome this difficulty are extremely numerous and could not be even mentioned here.

**Drying appliances.**—Attention is called to three appliances, which are considered standard and practical. These are the Mackensen, the Petry and Hecking and the Buettner and Meyer.

With the Mackensen apparatus (Figs. 148 and 149) several hundred tons of cossettes directly from the presses may be dried per diem. This apparatus consists of two long drums of forged

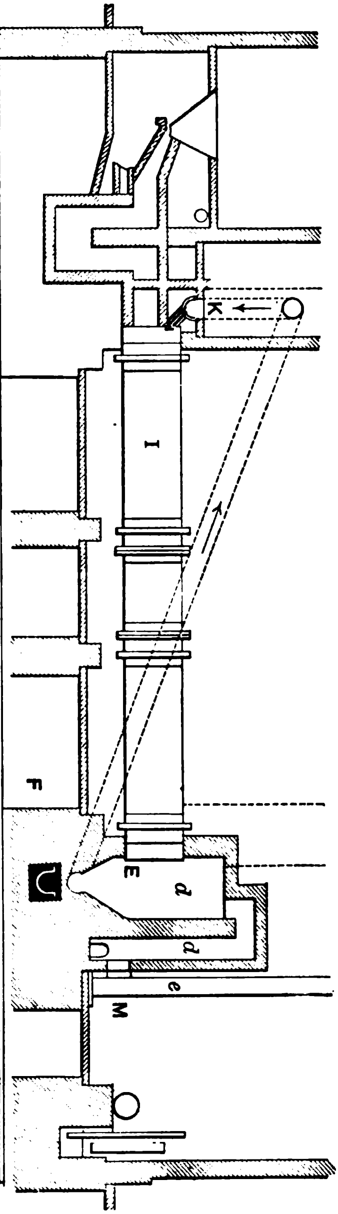



FIG. 148.—Vertical Section of the MACKENSEN Dryer.

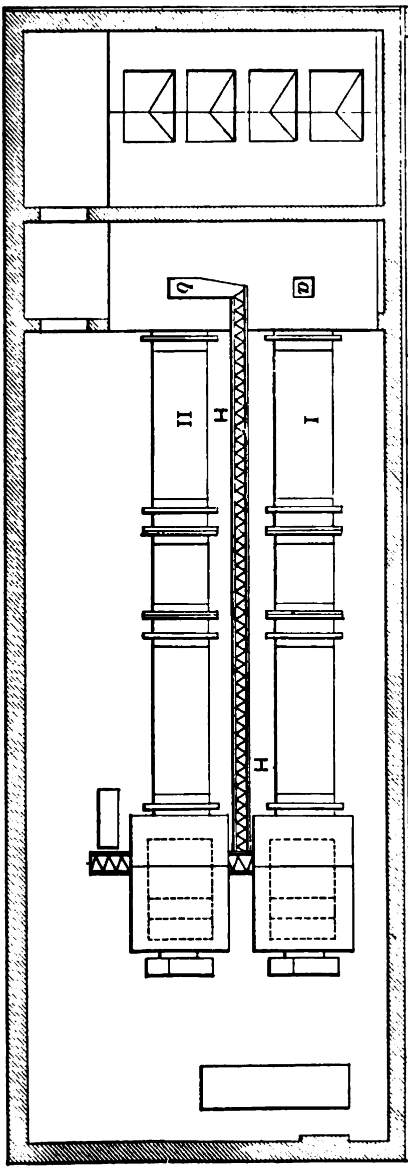



FIG. 149.—Plan of the MACKENSEN Dryer.

iron (I and II), about 14.4 meters long and 1.5 meters in diameter, each of which is composed of three sections, having iron rings at their extremities and working on trolleys. Their rotatory movement corresponds to a velocity of 5 to 6 revolutions per minute. The pressed cossettes fall by *K* into the first drum, passing through the same very slowly, and the hot gases from the furnace move in the same direction. In the first drum the temperature of these gases is about 140° to 150° C.

The motion of the cossettes is produced partly by the current of hot gases and also by a heating apparatus arranged as a spiral inside of the appliance. The early arrangement had a fire grate, over which air passed, in front of each cylinder. At *E* they fall into an oblique spiral *H*, which raises them and compels them to fall into the second drum, where the temperature is about 110° C. The hot gases are drawn off by the exhauster *M* and penetrate a dust chamber where the pulp that has been carried forward is deposited. The cossettes on entering the second drum contain from 50 to 60 per cent moisture. They give up their remaining moisture on entering the second drum II, and fall upon the spirals *F*, which conducts them to the elevator, by means of which they are carried to the loft or store-room. Two drums are sufficient for a factory slicing 150 tons of beets per diem. The motive power for all the drums, spirals, lifts, etc., is not more than 15 to 20 H.P. The expenditure for the entire plant is not more than 55,000 to 60,000 marks ($13,500 to $15,000), including building, chimneys, etc.

A residuum that had originally 85 to 90 per cent of water retains only 8 to 12 per cent when the operation is complete. Consumption of coal is about 180 to 220 kilos per 100 kilos of residuum dried. In Germany the product finds a ready market at about $27 per ton. The actual cost of drying by this method is $16.80 per ton of dried product. For a daily production of 18 tons the daily cost of working is about $300. The shape of the cossettes has an important influence on the working of the machine.

The Petry and Hecking dryer (Fig. 150) consists of several successive chambers in the shape of a trough, in which the agitators revolve, forcing the cossettes to move forward and projecting them from one compartment to another through the openings arranged in the separating division. These passages are not in each case in the same position, and, therefore, the gases and cossettes are forced to take a zigzag motion in passing through the

apparatus. In this dryer, as in the appliance already described, the gases move in the same direction as the cossettes, but before reaching the last compartment of the apparatus, the gases are drawn off by a ventilator *V*, which forces them to first pass through the so-called "cyclones" *C*, and then into the channel *K*, placed beneath the last heating chamber, which receives its caloric indirectly, *i.e.*, without danger of burning the cossettes. The cossettes leave this last compartment to fall ultimately thoroughly dried into the spiral *s*. It is important to rectify a very erroneous assertion advanced by the inventors of this dryer. They claim that the gases on leaving the division before their final exit, heat the last chamber and thus allow the utilization of the latent heat

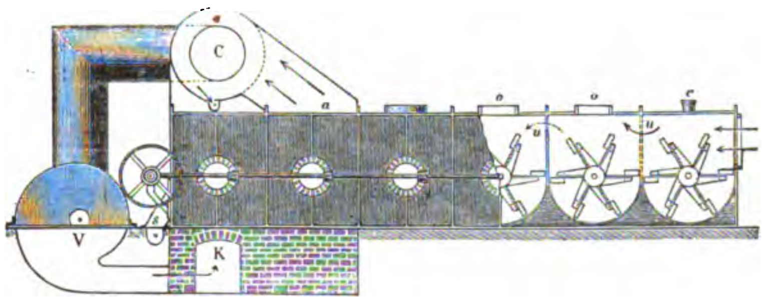



FIG. 150.—PETRY-HECKING Cossette Dryer.

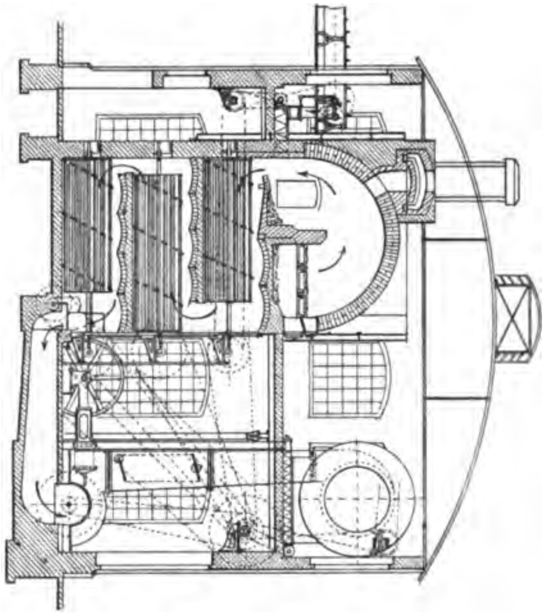
of water evaporation held in suspension by the circulating gases. This is an erroneous theory, as it is impossible for water evaporated from the cossettes to become reheated to such a temperature as to be again utilized for future work. From the time that water has passed into the condition of steam it becomes an inert gas, which mixes with the hot gases and can not condense in transmitting its heat to the cossettes, unless the residuum, for one reason or another, has become cooled at the very time that the water evaporated was liberated, and there is no possible reason for such cooling. Experiments show that 2539 kilos of coke are needed to dry 21,000 kilos of cossettes in 24 hours. One man can attend to an apparatus of 100 tons capacity per diem.

Notwithstanding the numerous efforts made to solve this problem from an economical standpoint, the BUETTNER and MEYER dryer actually holds its own to-day against all comers, from a practical point of view.

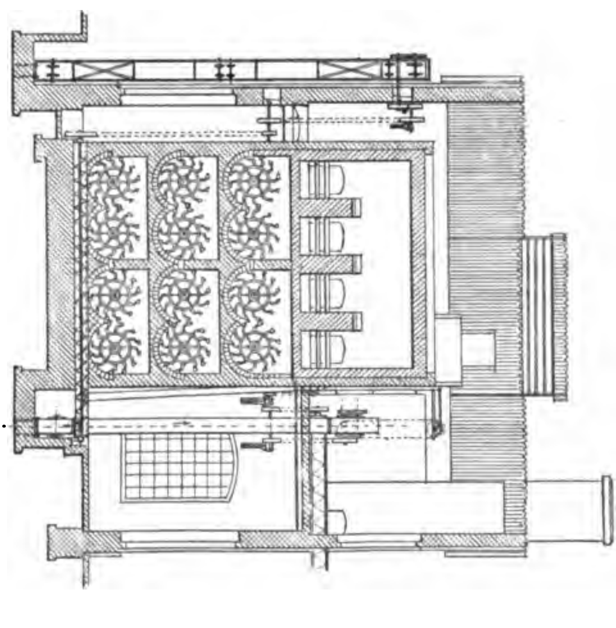
The BUETTNER and MEYER furnace is based upon two principles,

one of which is that the hot gases from the center of combustion which will evaporate the water of the cossettes, should be at the highest possible temperature in order to work economically; the second is that the cossettes cannot move in an opposite direction to the gases, but, on the contrary, should circulate with them until they leave the apparatus. The second principle is a natural outcome of the first, as it is evident that gases at the temperature at which they enter the apparatus (not less than 400° to 750° C., though at first it was argued that if the temperature was above 500° C. the cossettes would be burned), would immediately ignite if they were circulating in an opposite direction. The temperature of the moist cossettes which come in contact with these hot gases can never reach 100° C. so long as they retain moisture, as all the heat that the gases communicate to them serves in the transformation of this water into steam.

The BUETTNER and MEYER dryer (Figs. 151 and 152) consists of a large brick framework, upon the upper part of which is a furnace, surrounded by a dome in which the hydro-carbonated gases are finally consumed being transformed into carbonic acid upon coming into contact with the air. This frees the gases from the particles of soot which would contaminate the cossettes being dried and consequently give them an unpleasant flavor. The bottom of the dome is divided in two by a small brick partition, on the one side of which are collected the ashes, etc., carried forward by the circulating gases. The necessary suction of the air is effected by an exhauster and may be regulated as the occasion demands. When peat or other poor fuel is used it is first thrown upon a special grating, carbonized and allowed to fall gradually from layer to layer until completely consumed. On the lower and upper portion of the dome the gases are carried forward at the same time as the cossettes into the dryer proper, which consists of three semi-cylindrical layers, one over the other, each having a shaft that forces the spiral agitators to revolve through the intervention of conical gearings placed outside the dryer. These axes revolve at a velocity of 26 revolutions per minute. The cossettes are introduced into the dryer by an endless band carrier and spiral, and are deposited above the chamber of the dryer. This residuum passes through the apparatus, comes in contact with the hot gases and is rapidly dried. As already described above, there is no danger of the cossettes being carbonized, as the evaporation of the water they contain is sufficiently active to prevent their reaching a temperature of 100° C., and this is very



End Section:
FIG. 151.



Transverse Section.
FIG. 152.

BUETTNER-MEYER Dryer.

essential as above that temperature the albuminoids of the cossettes would be rendered very much less digestible.

**Temperature of cossettes being dried.**—According to the experiments of KOHLER the temperature of the cossettes in this dryer never reaches even 90° C., and in his laboratory oven experiments, in which the drying was done at 90° C., the dried product had coefficient of digestibility less than that of the dried cossettes obtained in the BUETTNER and MEYER furnace.

The agitating arms of the spirals are not combined, as one might suppose, to push the cossettes forward and force them out at the end of the apparatus; they are, on the contrary, arranged so as to compel them to circulate in the opposite direction from which they entered, but owing to the current of hot air they become dryer. The lighter portions are carried down to the second division, where the spiral arm arrangement raises the cossettes and brings them again in contact with the hot air until the moment when they are carried to the lower division of the apparatus. The cossettes are constantly brought in contact with the hot gases, and do not reach the bottom of the dryer until they have become sufficiently light to be carried forward by the circulating gases.

From what has just been said it becomes evident that the cossettes are raised continuously by the revolving agitators until the hot gases have rendered them sufficiently light to be carried a little farther each time until they reach the exterior of the upper trough, from which they fall into the compartment directly beneath, always coming in contact with the circulating hot gases. Then they pass through the three divisions of the apparatus and finally fall into the cylindrical trough at the bottom, in which is a revolving spiral that forces the dried residuum to the exterior of the apparatus. As the circulating gases always carry a considerable amount of cossettes in suspension, this would entail an ultimate loss; so before leaving the dryer the gases are forced into a "cyclone" where the particles in suspension are deposited and collected to be subsequently added to the dried cossettes. A special chimney is connected with the dome of the dryer and serves for starting the fire. As soon as this cupola is sufficiently hot, and after the cossettes enter and the exhauster is working, the chimney is closed. This chimney allows the escape of the gases of combustion when the supply of fresh cossettes is less than the practical efficiency of the apparatus, due, for example, to a stoppage in the general working of the factory from which the supply is obtained. Under such con-

ditions the cossettes would be burned if some means were not adopted to meet the emergency. Furthermore, the chimney gives an entrance into the furnace and permits air to circulate in the dryer when necessary, by which means the gases may be cooled. The apparatus is regulated in such a way that the cossettes on leaving the dryer are sufficiently desiccated and the gases cool enough to attain the saturation point, without, however, being sufficiently cool to allow the water to condense. By approaching as nearly as possible this point of condensation the economical working of the dryer is attained.

**Complete drying unnecessary.**—According to BUETTNER and MEYER the final temperature in their dryer should be 110° C., which is sufficient to prevent the condensation of water without in any way destroying the ultimate value of the dried cossettes. By lengthening the time that the cossettes remain in the dryer any desired degree of dryness may be obtained; it would be possible to evaporate the water contained completely. However, this would be unnecessary, as the dry residuum would reabsorb 12 per cent to 15 per cent of moisture when coming in contact with the air. BUETTNER and MEYER do not go beyond a limit of 88 per cent of dry matter which corresponds with the amount of dry substance in hay and other dry forage. In order to regulate the temperature of the furnace and the exit of the gases special appliances are attached to the dryer permitting the air to enter in the desired quantities.

It is to be noticed that the amount of cossettes entering a furnace is an important factor in determining the final temperature of the gases. The smaller the volume of cossettes in the dryer the greater the tendency of the temperature to rise. This may be readily explained, as under such conditions a large portion of the caloric is not utilized for the evaporation of the water of the cossettes. The working of the dryer and the suction of the air should be regulated so as to correspond to the amount of cossettes entering the apparatus and the volume being dried an excess of air would always cause a fall of temperature. The variations of temperature are very slight in the BUETTNER and MEYER furnace owing to the mass of masonry of which the dryer consists, which itself constitutes a sort of heat regulator. The initial and final temperature of the gases should be most carefully watched. The first can oscillate from 200° to 300° and has evidently an enormous importance. An excessively low temperature indicates that too much air has been mixed with the hot gases, and there is no question but what it is far better to evaporate water directly with fuel than to reheat the air. The

higher the initial temperature the greater will be the economical working of the dryer.

FETTBACK has analyzed the gases of this dryer in order to make sure that they are supersaturated with moisture. By observing the temperature shown by the moistened thermometer and that of the dry thermometer, and also the pressure indicated on a barometer, it becomes possible to ascertain the relative hygrostatic condition of these gases. Specially arranged diagrams show the influence of the volume of the cossettes to be dried upon the final temperature of the gases and also their relative moisture.

When there are defects in the dryer they may be recognized by a fall of temperature of the gases and their comparative moisture. The regulating of the dryer may, to a certain extent, be done by ascertaining its practical working efficiency, allowing for the utilization of the caloric of the fuel.

The formula proposed by RYDLEWSKI for the calculation of the efficiency of a cossette dryer is as follows: Suppose that $Q$ is the weight of the fresh cossettes, and $q$ the weight of the dried cossettes, $t$ the temperature in degrees centigrade of the moist cossettes, and $p$ the weight of the coal, while $c$ is the number of calories liberated by the combustion of one kilo of coal.

$$\text{Calories utilized} \quad C=[Q-q]\,[637-t].$$

$$\text{Calories furnished } C'=cp.$$

$$\text{Practical efficiency } x \text{ per cent}=\frac{100\times C}{C'}.$$

The application of this formula has given for the BUETTNER and MEYER dryer, as well as for the PETRY and HECKING apparatus, an efficiency of 82.04 per cent. This formula enables one to ascertain within what limit it is possible to introduce moist cossettes into the dryer at a variable temperature, and to what extent temperature has an influence on its efficiency. A rise of temperature of 30° to 35° C. means certainly an economy of 5 per cent in fuel.

**Objectionable feature of dryers.**—Some objections have been made to the BUETTNER and MEYER dryer, and also to the MACKENSEN appliance, on the ground that there is an important loss of dry matter carried forward by the hot gases. Some authorities have declared that this loss is 25 to 30 per cent and even 40 per cent. This, without doubt, is a great exaggeration. RYDLEWSKI has shown beyond cavil that when the dryer is conducted as it shoud be the

loss is not greater than 2.45 per cent of dry substances, or 0.16 per cent calculated upon the basis of the weight of the entire beet. This is especially true in the BUETTNER and MEYER dryer. On the other hand, KOHLER declares than in his investigations the losses of dry matter are 0.1 per cent of the beets worked, and 1.7 per cent of the total dry substances contained in the desiccated cossettes.

The efficiency of the dryer is about 400 kilos of dried cossettes per hour, and the consumption of fuel (coal) about 360 kilos. Four hundred kilos per hour represents about 9600 kilos per diem, containing 8700 kilos of dry matter, which corresponds to 75,000 kilos of fresh pulp. The amount of water evaporated is

$$75{,}000-9{,}600=65{,}400 \text{ kilos.}$$

The consumption of coal is 8700 kilos and consequently the fuel consumption per kilo of water evaporated is about 8 kilos. The cost of the dried cossettes, including sinking fund for money invested and all other items, was about $16.00 per ton, or $1.59 per 100 kilos. This is certainly in excess of what it should be and may be due to the kind of fuel used. Some say that to work 20,000 tons of beets the plant would cost at least $20,000.

**The steam-drying method** for the complete desiccation of cossettes is said to be a new departure and has met with great success in Austria. The plant recently built is for a 900-ton factory, and cost about $80,000 in that country. All calculations made, it is estimated that if the dried cossettes sell for $2 a ton the daily profits will be $200. The daily consumption of coal is about 100 pounds per ton of beets handled at the factory. By this method there is no danger of the residuum being burned by overheating, as is frequently the case with other modes of drying. It is claimed that nearly all the dry substances contained in the original beet are to be found in the final dried residuum (?), averaging 90 per cent. The residuum cossettes, after being pressed in a KLUSEMANN or BERGREEN press are carried by a moving apron to a trough with revolving horizontal agitators and heated with exhaust steam circulating in a jacket. The residuum is kept at a temperature of 40° to 45° C. for a considerable time, and is subsequently run into special presses very much of the same design as the KLUSEMANN. To each press there is attached an apparatus not unlike a meat chopper in its general construction. After the subdivision of the fibre, the residuum is carried by an endless screw to the dryers,

each of which is about 2 meters wide, 6 meters long and 5 meters high. In its interior are four horizontal troughs, placed one over the other, each of which has a steam jacket. In each trough is a rotating, horizontal, tubular cluster, through which steam circulates, and the hashed cossettes are consequently heated not only in the troughs but also during their rotating motion. The product being dried falls from one trough to another and circulates the entire length of each. When the dried cossettes finally leave the apparatus, another rotating device, in which there is no air, helps to empty them. The moist air from the oven is removed with a ventilator, the air passing through an arrestor which retains all the solid particles in suspension. The entire motive power is transmitted by gearing outside of the dryer. The dryer proper is metal, but the exterior covering is wood. The dried residuum leaves the dryer at 30° C. In different parts of the dryer the maximum temperature is 110° C. It is maintained that the following transformations take place: One hundred kilos of residuum pulp with 10 per cent dry matter may be considered to have been obtained from 200 kilos of beets, giving 67 kilos of cossettes with 15 per cent dry matter and only 11 kilos of dried product containing 90 per cent of dry matter. SPERBER's experience appears to show that there was needed for the drying 80 kilos of coal per 100 kilos of dried cossettes, without allowance being made for the motive power. Calculated upon a basis of 1 ton of beets, this means, all facts considered, that 120 kilos of dried product demand 110 kilos of coal. For the production of 10 tons of dried cossettes in 24 hours, there is needed a force of 50 H.P.

In the question of fuel consumption it must not be forgotten that the drying is done during the regular sugar campaign, and the steam used is simply the exhaust from the various pieces of apparatus of the factory. The daily capacity of the dryer may be increased by adding an oven to the series. It is claimed that with this apparatus and without any additional device, it is possible to use the dryers for mixing dried cossettes with residuum molasses. The device is so simple that a drawing was considered unnecessary to convey to the reader the idea of its general construction.

The THIESEN dryer consists of a large vertical cylinder in which are placed alternately funnels attached to the sides, and a sort of plate or dish fixed to the axis of the cylinder. Special scrapers are placed on the axis of the dryer, which brush the funnels and

force the substance being dried to fall upon the plates. The substance to be dried enters at the top and leaves at the bottom of the dryer. This appliance is, however, not intended specially for drying cossettes. A great many other apparatus have been proposed both for steam and direct heating. None of them is to be found in the sugar factories at this time, and but very few of them have been really tried in practice and may be overlooked. To describe them is beyond the scope of the present book.

**Composition and appearance of the dried residuum.**—The dried cossettes consist of fragments, about one inch in length, and light green in color. To the touch they are rather resistant and break readily between the fingers, especially when they have been dried too much. Their average composition is as follows:

AVERAGE COMPOSITION OF DRIED COSSETTES.

| Substances. | Analysis of König | Analysis of Pott. |
|---|---|---|
| Water | 15.57 | 10.0 |
| Nitrogenous substances | 7.63 | 7.5 |
| Fatty substances | 1.09 | 1.0 |
| Non-nitrogenous substances | 49.65 | 58.4 |
| Fibre | 18.22 | 17.1 |
| Ash | 4.19 * | 6.0 |
| Sand | 3.65 | |

* Of which 0.398 oxide of potassium, 0.21 phosphoric acid.

**Concluding remarks.**—Without doubt, as has been pointed out, the dryers consisting of several floors have given the best results. As shown in Figs. 151 and 152, the cossettes enter at the same time as the hot gases which have a temperature of from 800° to 1000°. The gases should be freed as far as possible of the ash or cinders in suspension, suitable fuel used, and grate distribution effected. The cossettes are kept in constant motion by horizontal shafts with arm attachments. The lighter dried particles are carried along with the circulating hot air towards the exit, while the heavy moist cossettes remain in the dryer until their desiccation is completed. Under these circumstances, the product is very uniform in quality.

The difference between the drum systems consists mainly in the mode of introducing and circulating the gases. Each drum of a combination should be specially heated and kept supplied with

cossettes, while a dryer of the same capacity as a system of several drums has but one furnace and one cossette distributor. The supervision and regulation of the working of several drums is always more complicated. If the person in charge neglects his duty the consequences are always more serious with this type of dryer than with furnaces. The cossettes may then be submitted to too much heat, the heating may last too long, or they may be insufficiently dried, which considerably lessens their keeping powers. With proper care, however, the dryers with drums give satisfactory results.

A multiple-effect method for caloric utilization in drying residuum cossettes has not proved a success. Consequently one's efforts should be directed toward utilizing, under the best possible conditions, the caloric of the fuel burned, and the new dryers allow 80 per cent of the total heat given off to be used. It has not yet been proved whether a real and appreciable transformation of the constituents of the cossettes is brought about during their desiccation. Apparently their digestibility is slightly modified, but this depends upon the nature of the desiccation. The ash percentage of dried cossettes, calculated upon the basis of dry material, is always higher than it is for moist cossettes for the reason that in the former cinders held in suspension by the circulating gases are always present. The quantity of dried cossettes that one obtains from 100 parts of beets depends upon the pressure in the presses, the percentage of sugar in the fresh residuum, and also upon certain losses. If it is admitted that the pressed cossettes contain 11 per cent of dry matter and the desiccated product 88 per cent, then 8 kilos of the pressed cossettes would be needed to produce 1 kilo of the dried product, making no account of the losses which may vary from 2 to 5 per cent.

Molasses is frequently added to the fresh residuum from the battery before drying to keep the proportions the same as when obtained at the factory. Consequently to 100 parts of pressed cossettes there are added about 4 to 5 parts of molasses. The cossettes soon absorb the molasses and their subsequent drying is performed as usual. This product appears to undergo very little change during desiccation. Vibrans points out that when molasses has saturated the cossettes they cannot be dried without important losses. A crust is soon formed on their surface which prevents the evaporation of the water contained in the cells. Under these circumstances the cossettes, or at least the sugar, is burned.

To overcome this difficulty it is proposed to inject into the dryer and in contact with the fire a steam jet or a water spray, which will tend to surround the cossettes with a protective layer and prevent the burning action of the hot gases which are met on entering the apparatus, thus allowing the complete drying of the cossettes by cooler gases from other parts of the dryer.

# CHAPTER IV.

## PRELIMINARY EPURATION AND HEATING OF DIFFUSION JUICES.

THE raw beet juice as it leaves the diffusion battery is cloudy, slightly yellow or gray in color, and soon becomes darker when exposed to the air, turning nearly black after a few minutes. BERTRAND * declares that this coloration is due to the action of a soluble ferment, an oxydase, contained in the juice. According to GONNERMANN † the phenomenon cannot be attributed to tyrosin, as it does not turn black under the influence of this oxydase; in fact, the chemical in question becomes inactive in hot, slightly alkaline juices. Earlier investigation showed that the substance upon which the oxydase has the most influence is acetic dioxyphenyl, which is the outcome of the action of a zymase ‡ upon the tyrosin. EPSTEIN'S § experiments show that the dark coloration of beet juices is not produced when air does not come in contact with the juice.

**Composition of diffusion juices.**—Diffusion juices contain almost all the soluble substances which were contained in the original beet and subsequently became dissolved in the battery. It is interesting to note the names of the most important, though they are so numerous that a complete list cannot be given.

*Inorganic substances:* Potassium, sodium, calcium, magnesium, phosphorus, nitrogen (in the form of nitrate), sulphur, silica, chlorine, and oxygen.

*Organic substances:* Saccharose, invert sugar, raffinose, oxalic acid, malic acid, citric acid, pectic substances, asparagin, betain, albuminoids, and enzymes.

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* Bull. Ass., **14**, 19, 1896.
† Z., **48**, 360, 1898.
‡ D. Z. I., **25**, 350, 1900.
§ Oe.-U. Z., **28**, 904, 1899.

The density of diffusion juices varies from 12° to 15° Brix with 10 to 13 per cent of sugar.

The analyses made by the leading authorities, such as ANDRLIK, URBAN and STANEK,* differ to such a degree that in the table herewith only the extremes are given. The analyses were upon 100 parts of dry material obtained from juices which had an apparent purity of 87 to 88.8.

ANALYSES OF DIFFUSION JUICES.

| Constituents. | Minimum. | Maximum. |
|---|---|---|
| | Per Cent. | Per Cent. |
| Total nitrogen | 0.612 | 1.313 |
| Nitrogen in the form of | | |
| Albuminoids | 0.170 | 0.407 |
| Nitric acid | 0.0006 | 0.026 |
| Ammoniacal compounds | 0.056 | 0.166 |
| Amide acids | 0.161 | 0.436 |
| Oxalic acid | 0.14 | 0.99 |
| Ash (carbonated) | 2.75 | 4.17 |
| Potassium oxide | 1.15 | 1.79 |
| Sodium oxide | 0.09 | 0.19 |
| Calcium oxide | 0.03 | 0.17 |
| Magnesium oxide | 0.23 | 0.43 |
| Ferric oxide and aluminum oxides | 0.03 | 0.08 |
| Insoluble residuum in hydrochloric acid | 0.04 | 0.13 |
| Anhydrous phosphoric acid | 0.34 | 0.64 |
| " sulphuric acid | 0.16 | 0.28 |
| Chlorine | 0.05 | 0.13 |

The acidity corresponding to 5.6 to 18.9 cc. of normal caustic potash per cent grams of dry matter.

CLAASSEN'S † analysis shows that the invert sugar percentage in diffusion juices is very variable. He insists upon it that the reducing sugars found by analysis are not exclusively made up of invert sugar. The oxalic acid percentage in the dry substances of diffusion juices, according to ANDRLIK and STANEK,‡ varied from 0.14 to 0.99 per cent. In the early analyses of diffusion juices the pectic substances appeared to be in great abundance; but the experiments and analyses of WEISBERG § showed their percentage to be very small. A very misleading fact, frequently met in the working of diffusion juices, as pointed out by PELLET ‖ is that the

* B. Z., 24, 205, 1899.

† Z., 41, 230, 1891; D. Z. I., 17, 1371, 1892; D. Z. I., 18, 337, 1893; C. 4, 793, 1896.

‡ B. Z., 24, 58, 1899.

§ Bull. Ass., 6, 440, 1889.

‖ D. Z. I., 23. 1255, 1898.

purity is higher under ordinary conditions of working and with normal beets than it is in the juice obtained in the laboratory by direct pressing. CLAASSEN also points out that in working a battery one cannot be guided by comparing the purity of the juice drawn off with that of a laboratory analysis. Recently, however, it has been claimed that by the KRAUSE method, in which a diffusion is obtained from very fine pulp, the juices in question have a greater similarity than heretofore.

**Micro-organisms and fermentations in sugar factories.**—Among the important causes of alterations in the composition of diffusion juices may be mentioned the action of numerous micro-organisms that are brought into the factory on the surface of the beets. It has already been pointed out that these lower forms of life may seriously obstruct the general working of the battery. Evidently it is important always to use care and cleanliness, as by so doing this difficulty is greatly diminished. But do what one may, as the micro-organisms on the fresh beet slices continue to be introduced into the juices, difficulties are frequently contended with in their working, and the fermentations that follow cause serious sugar losses. To prevent, or at least diminish, the influence of these micro-organisms the diffusion juices should be rapidly handled and kept alkaline, whereby the difficulty is reduced to a minimum. SCHOENE,* in his experiments with factory diffusion juices, frequently found 3,374,000 of these organisms per cubic centimeter. The greatest number were found in the last diffusor upon which the water pressure exerts its action, while in the middle of the battery the number decreased with the temperature. With the exception of the family known as thermophiles, they are destroyed at 60° to 70° C., while their spores will have resisting powers and, when the temperature falls to 30° or 40° C., will then multiply rapidly and thus influence the sugar inversion. Under ordinary conditions these losses need not be dreaded owing to the high temperature maintained.

Juices drawn from the diffusors contain a greater number of micro-organisms which are largely destroyed during carbonatation, but again increase during the concentration in a multiple effect and the vacuum pan. According to SCHOENE the butyric ferment, with which the clostridium is frequently confounded, may be found in the juice. The real lactic ferment is seldom found. In sugar

* Z., 51, 453, 1901.

factories the bacteria that is most destructive is the leuconostoc mesinteroides, but it must exist under special conditions to produce a gelatinous mass. Among the perturbations resulting from this are the difficulties in filtration, evaporation of juices, and graining of the syrups. There are also other varieties of streptococcus and many other kind of cocci which develop at 45° C., and have an objectionable influence on the juices causing them to ferment rapidly. This ceases during carbonatation, and like the difficulties occurring during the later handling of the juice show that there are other sources of the trouble and other centres of infection.

Upon general principles it may be admitted that all sugar-factory juices contain Clostridium mesintericus and Bacterium subtilis, which have enormous resisting powers. Some authorities claim that they continue to remain active even after having been submitted to the action of steam at 100° C. for 16 hours (?) In concentrated juices they bring about rapid alterations. During filtration a large number of these micro-organisms are eliminated, and it is claimed that important advantages would be derived by filtering the hot diffusion juice.

The authorities do not agree as to the efficacy of antiseptics for preventing the development of these special bacteria. Without doubt the most effectual means is heat. In experiments at temperatures of from 80° to 90° C.* the number of micro-organisms were reduced 50 to 1. It is evidently desirable to submit the juices to carbonatation as soon as possible so as to lessen the effects of the destructive influence of the ferment germs. But if this operation is not conducted at a high temperature the presence of the clostridium will be plainly shown. They also develop in the sweet water from osmogenes, due to the existence of a high percentage of non-sugar which favors their activity. These organisms resist a temperature of 90° C. for 30 minutes. The temperature in evaporating appliances prevents their development, but the cooling of the resulting syrup when in contact with the air favors the rapid increase of the clostridium which may accidentally contaminate the mass. LAXA † has called attention to the existence of clostridium germs in fresh *massecuites* upon leaving the pan and also in all the after-products. He does not believe that the increase of invert sugar is due to their presence, but admits that they are possessed of inverting power.

* Z., **51**, 453, 1901.

† B. Z., **24**, 423, 1899–1900.

**Pulp separators.**—Besides the dissolved foreign substances and the micro-organisms in diffusion juices there are also floating particles of beet pulp or cossettes held in suspension, and the preliminary epuration of diffusion juices is principally to eliminate such particles as have not been separated during the operation of straining. CLAASSEN says that this elimination is of considerable importance and should under no circumstances be neglected. There are several objections to the presence of these substances. They are deposited on the heating surfaces of many of the appliances used and thus diminish their efficiency; if they remain until the defecation of the juice they are decomposed into gelatinous compounds by the lime, which reduces very considerably the quality of the product. Furthermore, during the carbonatation they are transformed into new precipitates and render the juice filtration in the filter presses excessively difficult, especially when present in large proportions.

For the mechanical filtration of diffusion juices so-called pulp separators are used, of which there are many varied combinations. The characteristic possessed in common is that the filtration is accomplished through a perforated metallic screen, and the filtering surface is kept free from deposited fibres by suitable scraping or brushing devices. The work accomplished by these pulp separators is more satisfactory when the perforations are small, and the total filtering surface should then be proportionately increased and the cleaning arrangements perfected.

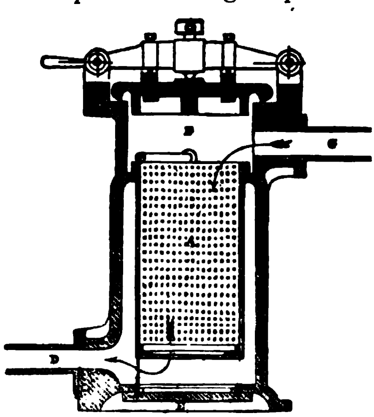

FIG. 153.—Standard Pulp Separator.

The pulp separator generally used is a vertical cylinder (Fig. 153) closed on top by a suitable cover working on a hinge. At the upper portion of this receptacle is the entrance pipe *G*, and the exit opening *D* is generally at the bottom. Between these is placed a perforated sheet-iron basket, in which the pulps in suspension are deposited, the quantity evidently depending upon the size of the perforations in the bottom plate of the diffusors. To economize time it is desirable to have two of these baskets, one being placed immediately in position when the other is removed, and

ASKAN MUELLER'S apparatus (Fig. 154) effects a still greater saving. It is very simple in its arrangement, consisting of concentric cylinders, the outer one, *A*, of cast iron and the inner one of perforated sheet iron. The juice enters at the top and passes through the perforated sides to escape by a side pipe. The suspended pulp is thus separated and remains on the filtering surface. When the

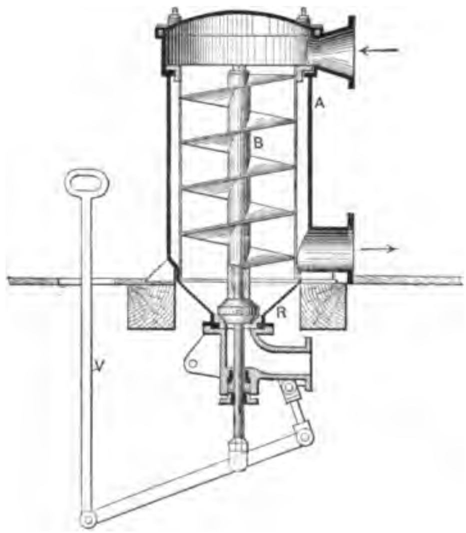


FIG. 154.—MUELLER Pulp Separator.

receptacle is to be emptied of its separated pulp, the lever *V* being raised, connects with the spiral *B* and opens at the same time the valve *R* communicating with the diffusion battery. The juice during its downward motion carries with it all the pulp scraped from the sides of the filtering surface during the upward movement of *B*, and when the surface is free from all adhering cossettes the lever is lowered and the operation of pulp separation continues as before.

Another excellent apparatus is the WAGNER pulp separator (Fig. 155) in which there are several metallic filtering surfaces. The juice enters from the diffusion battery at the bottom *A*, passes through the baskets and then circulates downward through *B* to the defecating tanks. The perforations become smaller and smaller, and thus all the suspended particles, whatever their size, are removed. When the surfaces of the baskets need cleaning the two lower valves *D* and *C* are closed, and *E*, the one con-

necting with the battery, is opened. Thus the circulation of the juice is not checked. Steam introduced through *G* takes with it all the adhering pulp and carries it out through *F*, which valve at other times remains closed.

The MAY appliance has also been used. It consists of three semi-spheres and cones placed one over the other. The smaller one has a filtering surface and receives the juice under pressure

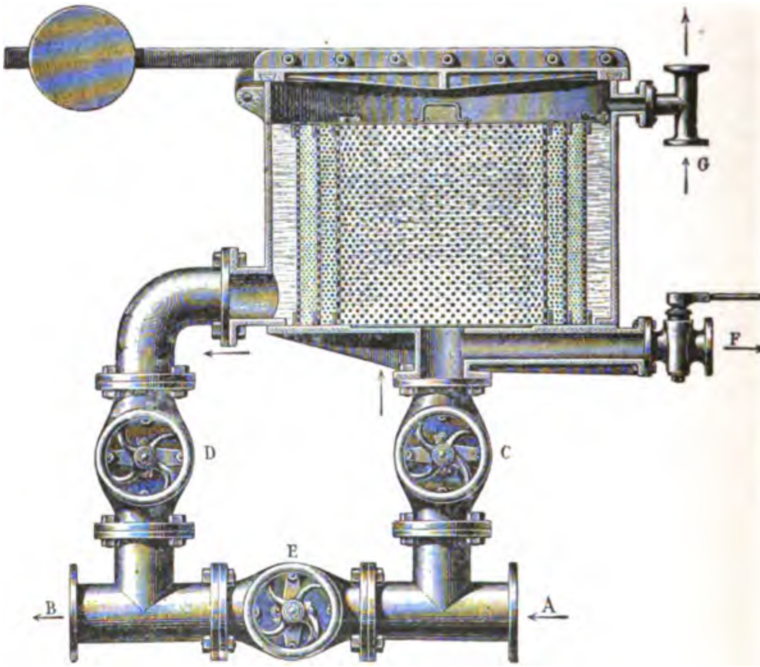


FIG. 155.—WAGNER Pulp Separator.

through a lower pipe, the second acts as a funnel for the filtered juices and the third as a hopper for the evacuation of the residuum of filtration. The perforated iron is cleaned either by hand or with special brushes.

The position of the pulp separator in front of the reheaters should be such that the return of the arrested cossettes to the diffusors may be readily accomplished, thus preventing the waste of the juices therein contained. The contents of the pulp separators are emptied into the diffusor when it is half full of fresh cossettes. This direction must be followed, for the waste consists of small bits which, when placed in the midst of fresh beet slices,

will in no way obstruct the circulating juices. If the cossettes were emptied upon the bottom filtering plate the perforations would become clogged and the circulation would be correspondingly poor.

**Measurers.**—After the juice has run through the pulp separators it passes into the measuring tanks or receptacles. These are of several types, some of them working automatically and recording simultaneously the number of times they have been filled and emptied. This allows perfect control of all the following operations, such as defecation, etc. In some countries the fiscal laws demand that the measurers shall have overflows. This arrangement has the advantage of always giving the same volume independent of the man in charge; but, on the other hand, it is objectionable in that the volume cannot be made to vary with the method of working the battery, or in other words, with the volume of juice drawn from the diffusor. Various devices have been suggested, but the simple receptacle with a float within sight of the battery man seems to answer the purpose.

**Reheaters.**—Before the process of liming, the juices should be heated to 80° or 90° C. This is the temperature at which carbonatation is conducted, and notwithstanding the fact that for nearly a century it was customary to heat the juices after liming the practice has now been abandoned. When the juice is heated before liming there follows a coagulation of the albuminoids, and the lime with which it comes in contact has then no longer the same action and the possibility of the albumin remaining in the carbonatated solution is lessened. One of the objectionable features in heating limed juices is the danger of an insoluble saccharate being formed, which would occasion a considerable sugar loss. The resulting combination is not readily decomposed by carbonic acid, and, therefore, the limed juices would leave increased deposits on the pipes of the reheaters, thus diminishing their heating efficiency.

In the measurers the diffusion juices drawn off vary greatly in temperature, depending upon the mode of heating and the temperatures to which the fresh cossettes have been submitted. This variation is from about 0° to 40°, generally being between 25° and 35° C. In order to give the juices the caloric necessary for the defecation they are run through tubular reheaters, which may be either vertical or horizontal, open or closed. Their size is calculated by allowing for a comparatively small coefficient of transmission. The brass or iron tubes are distributed over one or two appliances

in order to obviate loss of time in case of stoppage. Another arrangement consists of one receptacle with suitable divisions, which may be isolated as the conditions of working may demand. This mode is adopted only when space is limited and is intended to meet an emergency. In Germany open reheaters are generally used, while in Belgium, France and Austria closed reheaters are preferred. As regards size and shape the latter do not differ very much from the calorizators used for the juices of a diffusion battery.

**Open reheaters** have the advantage that the tubes may be cleaned while the apparatus is in operation; but their very limited efficiency and the fact that the juice is exposed to the action of the air are great disadvantages.

In a large iron cylinder, *A* (Fig. 156), closed at the bottom, is placed a tubular heating surface *B* with entrance steam valve *V*.

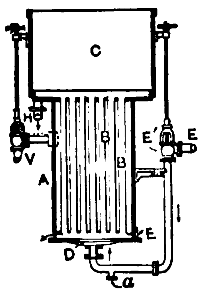


FIG. 156.—Open Reheater.

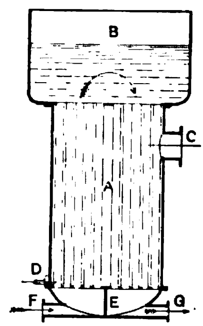


FIG. 157.—Open Reheater with Double Circulation.

The exit for the condensed water is at *E*, and there are special purgers for the escape of the air when heating by steam under pressure. Above the tube cluster is the receiving chamber *C* for the juice, the capacity for which varies with the requirements. *C* in reality is a sort of waiting tank, and is placed at sufficient elevation to give a pressure for forcing circulation. The juice enters at *E′*, flows downward and then into the apparatus below the lower tubular disk *D*, circulates through the pipes and escapes at *H*, the steam circulation being on the outside. Another type of open reheaters is shown in Fig. 157, in which the juice enters at *F*, rises through the tubes *A*, and descends to pass out through *G*. *E* divides the bottom in two. The steam enters at *C* and the water leaves at *D*.

An artificial circulation of the juice to increase the efficiency of reheaters may be brought about by means of pumps or spirals

and by special mechanical devices which at the same time clean the tube. Reheaters of a new design are open on top. In the upper cylinder there are two spiral agitators, one of which forces the juice upward and the other downward. The rapid circulation of the liquor prevents all possibility of incrustation on the heating surface.*

For some years it was customary to reduce the section by introducing iron rods into the tubes of reheaters. The rods were encircled by wires,† forming spirals, on which the thin layer of juice circulated during its downward motion, and the heat transmission was found to be very satisfactory. To keep the tubes clean and free from deposits the rods were held on a disk which could be raised or lowered. In order to obviate the difficulty of overheating (resulting in boiling and the possible overflow of the open reheaters), it is desirable to have a cold-water pipe on top which is used when needed. Experience shows that in the upper juice reservoir forming part of the open reheaters it is well to have a thermometer, so that the operation of heating may be carefully followed.

**Closed reheaters.**—The closed reheaters are, without doubt, more economical and effectual in their working. The activity of circulation depends upon the arrangement of the tubes in clusters through which the juice successively circulates. In reheaters of this kind there is a much smaller deposit upon the heating tubes than in the open arrangement, which means a gain in their caloric efficiency.

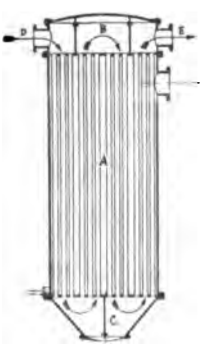

FIG. 158.—Closed Reheater with Multiple and Rapid Circulation.

A satisfactory type of closed reheater is shown in Fig. 158. The juice enters at $D$ and is forced to circulate from top to bottom; it then rises to $B$, descends through the tubes to $C$, rises again and escapes at $E$. The reheater of CAIL & Co. has a heating surface of 50 sq. m., and six sections or circulators through which the juice flows with considerable rapidity. Under these circumstances there are no deposits, and thus the transmission of heat by contact with the heated surface is increased. The air is drawn off from the top. There is a balanced

* D. Z. I., **27**, 1034, 1902. † C., **11**, 415, 1903.

closing door at the bottom which allows rapid and easy cleaning. The cocks are so arranged that the reheater may be disconnected from the general circulation if necessary. These reheaters may be made of any size, from 10 sq. m. to 150 sq. m.

The FIVES LILLE vertical reheater offers some special advantages over the horizontal type. The work it has to do, however, is entirely different from that of the latter style. It is intended for the heating of turbid juices from the first and second carbonatations, and utilizes for the purpose the vapors from juices being evaporated in one of the compartments of a multiple effect. As this reheater has to withstand considerable pressure special strengthening bands are placed on the outside. It connects with the scum pumps communicating with the filter presses. This apparatus consists of a sheet-iron cylinder holding two tubular plates and steel tubes which are heated externally with steam, and on each of the tubular plates is bolted a cast-iron box divided into compartments by partitions, the respective positions of which are such that the liquid to be reheated enters by the arrival pipe on the upper box and is forced to circulate from four to six times in the tubes and finally leaves the apparatus by the evacuation pipe placed in the same box. This circulation is very rapid, and is intended to increase the coefficient of transmission of heat and obviate the possibility of the particles in suspension in the tubes adhering to their inner surface. The upper and lower boxes are kept hermetically closed by a rubber joint and may be opened and shut at will. In connection with the tubes there are several attachments and a pipe which allows the free exit of the ammoniacal vapors. The entrance and exit tubes for the liquid have each a thermometer which permits one to follow the work being done. The juice cocks are so arranged as to allow the liquid to leave the reheater in case a cleaning is needed. These reheaters are found in recently built factories.

Reheaters of the special type for rapid circulation have lately undergone certain changes. When connected with a diffusion battery they may be arranged in clusters of three or four and heated either with the vapors of the first, second, third or fourth compartment of a quadruple effect. The pressure forcing the circulation may be at 3, 4 and even 5 atmospheres.

The transmission of heat is never greater than 16 calories per minute per square meter and per degree centigrade of the difference of temperature between the steam and the juice to be heated.

For high temperatures there were always obtained 6 to 11 calories. Such reheaters when properly constructed give satisfactory results, but their efficiency is very much below what they should yield according to theory. This is in a measure due to the incrustations, but mainly to the poor conductibility of diffusion juices. A thin film of liquid is heated against the sides of the brass tubes, but the centre of the column of liquid remains cold.* LEXA has attempted to increase the transmission by forcing the juice to circulate in a zigzag direction, whereby a certain mixing occurs at each turn. In the ABRAHAM reheater it is claimed that the forced circulation results in heat transmission of 19.2 to 27.1 calories, instead of 1.53 calories as in open reheaters, the juice changing its direction four times from the time it enters until it leaves the apparatus.

The FIVES LILLE horizontal reheater has a heating surface of 50 sq. m. This appliance is generally placed between the last compartment of a multiple effect and the barometric condensor, its main rôle being to regain a portion of the heat from the condensed vapors and assure the easy escape of the condensed water through the barometric column. This caloric may be employed for heating the water to be used in diffusion, or the juices from rasping stations upon their arrival at the central station. The heating surface is so calculated that the temperature of the water is raised from 15° to 45° C. These reheaters consist of an exterior sheet-iron or cast-iron covering holding two tubular plates and steel tubes heated externally by the steam during its passage to the condensor. At each extremity a box with compartments is bolted on the tubular plate so arranged that the liquid circulates six or eight times in the tubes. One of these boxes holds the pipes for the arrival and departure of the liquid. The tubes may be cleaned by opening doors placed on the boxes and kept hermetically closed by rubber joints in special grooves. These reheaters have cocks, thermometer attachment and a pipe for the evacuation of condensed water.

Among other horizontal reheaters may be mentioned that of HALLSTROEM, consisting of a rectangular compartment containing eight series of horizontal tubular clusters, a section of which is shown in Fig. 159. The juice circulates in the interior of the tubes. The juice chambers at the end of the tubes communicate in such a way as to force the juice to travel over considerable space before leaving the apparatus. The juice enters the apparatus at *a*, in the front chamber of the tubular cluster, No. 1; then goes to the

* C., **10**, 338*a*, 1902.

back chamber, No. 2, comes forward, passes into 4, 3, 5, then into 6 and 8, and escapes through *b*, connected with 7. The steam used for heating enters at *C* and leaves at *d*. To increase the distance travelled by the steam horizontal sheet-iron plates are so arranged as to force a zigzag circulation. The best results obtained with these appliances are with the steam at a low pressure from the last compartment of a multiple effect.

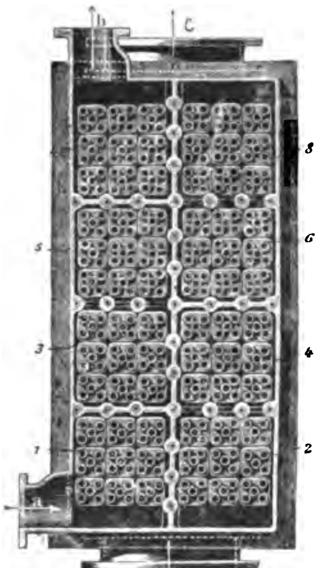

FIG. 159.—Horizontal Reheater, End View. (HALLSTROEM.)

CLAASSEN says that the best arrangement consists in a battery of small separate reheaters, which are made up of long tubes of comparatively small diameter, in which the juice circulates at a velocity of 1 to 2 meters per second. Notwithstanding the fact that the deposit is then comparatively slight, each reheater has valve attachments so that the tubes may be isolated when they need cleaning without the slightest interruption of the general working of the appliance. The transmission of heat is far greater in closed reheaters, and consequently the heating surface may be made much smaller and low-pressure steam used for heating.

Most beet-sugar factories have two reheaters, or rather two systems of reheating, the first of which utilizes the vapors from the last evaporating compartment of a triple, quadruple, etc., effect when on their way to the condensor, and thus heats the juice from 45° to 50° C. without cost. The second method depends upon the vapor of the first compartment and raises the juice to the temperature necessary for defecation—at least 70°, 80°, or 85° C.

The steam for reheating in beet-sugar factories when there is but one reheater should never have a temperature lower than 100° C., otherwise there would be constant danger of cold juices. The same conditions should exist in the second reheaters of the reheater battery. In some cases it would seem advantageous to use exhaust steam or steam from the multiple effect for heating. As the latter vapors cannot be used during the first stages of the

factory's working—which fact applies equally to all other reheating appliances of the factory—all the reheaters should be arranged so as to use exhaust steam from the engines. This arrangement makes them independent of the multiple effect.

CLAASSEN further says that at the commencement of the sugar campaign, or after a stoppage when the juices, appliances, and piping, etc., are cold, special attention should be given to the question of temperature, which should everywhere be slightly higher than actually necessary to make allowance for the caloric absorbed.

All reheaters should be so arranged as to be readily isolated for cleaning or repairing leakage. In order to determine the points of leakage the condensed water running from these appliances should be constantly examined for sugar. It may happen that the sugar losses are greater in the reheater than in the evaporator, owing to the difference of pressure between juice and vapors. This is especially true in the case of the reheater placed between the last compartment of a triple effect and the condensor. The difference of pressure may be considerable, and for this reason many engineers are unwilling to use reheaters under these conditions. KARLIK * estimates that the economy resulting from such combinations amounts to 1.5 kilos of coal per 100 kilos of beets sliced.

Experience seems to show that the capacity of the reheaters should not be excessive, as the juice would then remain in the receptacle an unnecessarily long time, and this always has serious consequences, especially as regards sugar inversion. The acid reaction of the juice has very little influence after a normal heating, but there is an inversion at 90° C. CLAASSEN says that to prevent complications of this kind, due to acidity, it may be found desirable to add to the diffusion juices, before they enter the reheaters, a certain amount of milk of lime, about 0.2 per cent, so as to render the juice slightly alkaline. By this means the deposits on the tubes of the reheaters are diminished. However, when lime is thus added to cold diffusion juices the scum presses do not give satisfaction, and, therefore, this preliminary defecation, which in most cases is unnecessary, has never been very generally adopted. There are also other objectionable features which have been already explained.

* B. Z., 23, 590, 1899.

Whatever be the shape of the reheater used it should always have at its lower extremity a pipe that may connect with the defecating tank and through which pass all the deposits scraped from the tubes of the apparatus during cleaning. The tubes of the reheater may also be corroded by the ammoniacal vapors unless carefully watched.

**Frothing in reheaters.**—Open reheaters have the advantage of allowing frothing upon the upper surface, and though these foams contain the coagulated albumen it has not been customary to remove them. A device * having this object in view consists in an appliance placed below the surface which has revolving wings made of wire cloth. The froth is pushed towards an opening where it is taken from the apparatus by a screw. To make certain of its removal and to prevent its being carried forward into the carbonatators the pipe through which the juice is drawn off has a bend which acts as a syphon and forces the juice to rise to a certain height above the orifice of the pipe. Under these circumstances juice only is carried forward and all the froth is removed by the revolving spiral.

The Pfeiffer † analysis of the dry matter of froths from diffusion juices showed that they contain 40 per cent albuminoids, the other elements of their composition being sugar and saline substances. Without doubt the froth in question has considerable nutritive value, and from an economic standpoint it should be mixed with the pressed residuum cossettes before they are sent to the dryer. Pfeiffer recommends that this foam be first mixed with molasses and then combined with the pressed cossettes before their desiccation.

**Cleaning of reheaters.**—As the tubes of reheaters become rapidly coated with deposits they must be constantly cleaned, otherwise their efficiency would be considerably lessened. The cleaning is usually done by scraping, and as the joints of the tubes come constantly in contact with the scraping tool they soon leak, and it is then necessary to unmount the appliance, resulting in much loss of time. As the reheaters are of considerable size a board forming a platform is placed upon the top during their cleaning, and upon this the workman stands, and it sometimes happens that he falls into the boiling juice and meets instant death. A new device permits cleaning during the full working

* Oe.-U. Z., **31**, 655, 1902. † D. Z. I., **27**, 2013, 1902.

of the reheater and does away with all possible danger to life. Over the upper openings of the tubes a specially arranged rolling carriage is placed which acts as a guide for the scraping tools, and as they work in the exact direction of the axis there need be no danger of blindly wearing away a joint. The tubes are of different lengths, and, therefore, the depth to which the scrapers enter must be regulated accordingly. The general arrangement of the carriage adjustor may be such as to permit it to move in any direction that may be given the heating tubes in order to obtain the maximum heating surface within the minimum space.*

A very practical mode for cleaning reheaters consists in boiling water containing 1 per cent of soda for two hours and completing the cleaning with metallic brushes fastened to long iron rods. Closed reheaters cannot be cleaned during operation, but must be emptied.

**Preliminary epuration of juices.**—For many reasons, among which may be mentioned the economy of lime which will be used in subsequent operations, and also the realization of a more effectual epuration than can be attained with lime alone, it has been proposed to submit the juices to numerous preparations when they leave the diffusion battery. The fact that by reheating beet juices, especially those that have passed through the filters, certain albuminoids are coagulated, has caused the use of an appliance, frequently termed a disalbuminator, through which the diffusion juices, heated above 80° C., are filtered to free them of albumin. But this idea seems to be based upon a fundamental mistake. By heating diffusion juices only a very small portion of the albumin is precipitated, and this substance cannot be separated by filtration owing to its special physical condition.

Claassen says that there is about 0.2 to 0.3 per cent albumin in diffusion juices, of which only 10 per cent may be coagulated; that is to say, 0.02 to 0.03 per cent of the juice, or a quantity that is hardly perceptible as far as the epuration of the juice is concerned, which shows that the use of expensive devices is not justifiable. The remaining albumin is soluble and cannot be coagulated; consequently the filtration of the coagulated albumin before defecation renders very little service, as during defecation it undergoes no decomposition and very little physical change. Filtration in the pulp separators is sufficient. Notwithstanding the fact men-

* S. B., Dec. 1899.

tioned, it is claimed that excellent results have been obtained by the use of the disalbuminators, but these advantages may be due to the efficiency of the pulp separators alone. If, however, the disalbuminators are of considerable size and the juices are not at all parts in continuous motion they may bring about certain complications owing to the influence of micro-organisms which necessarily cause juices to undergo many objectionable modifications. One of the greatest difficulties is to get a filter press that works with regularity and gives reliable results in the separation of albumin.

It is furthermore recommended for the preliminary epuration of diffusion juices that they be submitted to a special sulphuring or that, instead of sulphurous acid, baryta or an electrical current be the epurating agent. In the case of electricity experience shows that one should use soluble electrodes and electrodialysis for the purpose. Such means actually precipitate and eliminate the non-sugar as well as reduce the coloration.* But as all these substances are also precipitated by lime there is no advantage in substituting other agents, especially as the liming method is economical, and other epurators giving about the same, or even better results would not compensate for the additional expense.

Among the modes which have attracted the most attention of recent years may be mentioned the HARM and the LEHMKUHL processes. The first may be applied in the diffusor proper and has already been discussed under another caption. LEHMKUHL † adds 0.1 per cent of aluminum sulphate to diffusion juices to coagulate the albumin. It is claimed that the juice thus obtained is so pure that only 1 per cent of lime need be used for subsequent defecation. There is no danger that the aluminum sulphate will invert the sugar as the amount used is too small to have the slightest influence.

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* This question is fully discussed under another caption.

† D. Z. I., **26**, 1305, 1901.

# PART III.

## *EPURATION.*

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## CHAPTER I.

### LIMESTONE AND LIME KILNS.

**General considerations.**—Beet juices are chemically epurated with lime, and the excess of this substance is eliminated with carbonic acid. These two epurating agents are simultaneously obtained in the lime kiln. By the now obsolete mode of epuration very little lime was used, and as the daily working capacity of the sugar plant was comparatively small the quantity needed was purchased. When the comparatively modern sugar plants were introduced and the quantity of the lime used was increased it had to be eliminated by means of carbonic acid, which led to the building of lime kilns in connection with the factory proper. To PAYEN * belongs the credit of first suggesting that the manufacturer make his own lime.

**Limestone.**—Pure limestone consists only of oxide of calcium and carbonic acid, but as used in sugar manufacture it is never in a condition of perfect purity, the foreign substances with which it is found combined varying from 1 to 5 per cent.

*Selection.*—The selection of suitable limestone is of great importance, but its quality cannot be solely determined by chemical analysis, as such data would not show whether the product is readily burned, or whether the foreign substances present exert an objectionable influence. On these points the appearance and structure of the limestone give definite and positive information. As to the influence of foreign substances, their quantity is of less

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* Z., 2, 13, 1852.

importance than the manner in which they are distributed throughout the stone. Nevertheless it may be desirable to reject a limestone which chemical analysis shows to contain a large percentage of impurities. These generally consist of ferric oxide, aluminum, sulphur, magnesia, alkaline silicates, and frequently a heavy percentage of chloride of sodium in addition to organic substances.

These impurities are not only objectionable because they lower the purity of the juices, but they may also cause difficulties during the subsequent graining in the pan. Silica has a special influence upon the quality of burned lime because it considerably decreases the facility of slaking. Even with 6 per cent of silica there is danger of superheating the lime; that is to say, it will not readily slake by the liberation of heat. Alumina, iron, and magnesia when acting separately produce no objectionable effect, but the collective influence of the first two with silica causes the alumina to influence the superheating of the lime.

**Requisites as to quality.**—HERZFELD * declares that the lime kiln works to the best effect at 1200° to 1400° C. Clays have no action on lime, but if the limestone also contains silica there will be formed an acid silicate of alumina. With clay alone this chemical combination cannot be obtained unless the temperature of the kiln reaches 1600°, which is seldom the case. Iron aids in the alumina absorption, and when it exists in limestone simultaneously with clay and silica the hydraulic mortar is formed at 1300° C.

Magnesia has very little influence on the working of the kiln, but diminishes the purity of beet juices to which it is added. As it is soluble and not easily combined with carbonic acid it is most difficult to eliminate and is deposited on the various steam coils and tubes of the factory. The coils of the vacuum pans are frequently covered with it in combination with other substances.

It is important to note that ferric oxide continues to exert an effect during the entire process of sugar extraction, even the final product showing a grayish color due to its influence.

Pyrites is contained in many limestones and is decomposed by calcination into an anhydrous sulphurous compound. This transformation necessitates an increased draught in the kiln and augments the amount of fuel necessary to run it. The result is that the carbonic acid obtained is not of standard quality.

The percentage of sulphur contained in a limestone and exist-

* Z., 47, 913, 1897.

ing in the fuel has an undesirable influence on the actual slaking of the lime in that the sulphur contributes to the formation of sulphate of lime or gypsum which has an unfavorable action. Certain alkalies, usually existing only in very small quantities may, when in excess, bring about chemical changes that would also diminish the quality of the burned lime for the purposes intended.

Ordinary salt, or chloride of sodium, has in some special cases been found in limestone in considerable quantities, and this chemical may be carried by entrainment into the juice by the carbonic acid. As salts in general prevent several times their own weight of sugar from crystallizing the disadvantage of such impurities is self-evident. Sand and gravel are very objectionable for mechanical reasons, as they subject all the pumping appliances to considerable wear and tear.

The percentage of tars and bituminous compounds contained in a superior limestone is small. They have no special influence, but diminish in a certain degree the value of the lime rock under consideration.

**Water content.**—Limestone when taken from the quarry contains water in varying quantities; some of the stones used contain from 0.10 to 0.30 per cent, while the softer chalks frequently retain 16 per cent of moisture. They may be in a measure dried by exposure to the sun, but as a general thing they still have about 10 per cent of water. When burned in a kiln the resulting carbonic acid is never satisfactory, either in volume, or quality, and the quicklime remaining is proportionately small. The watery vapor set free in the kiln causes a great reduction in the efficiency of the working of the kiln and the various appliances that follow.

In marls there has been found 22 per cent * of water. Certain French marls used in beet-sugar extraction contain considerable water. When these soft stones are heated they fall to pieces under the expansion of the water that is too rapidly liberated, and this causes the clogging of the kiln. Generally, however, the limestone used is hard and contains very little water.

**Composition.**—The composition of several European limestones considered of excellent quality for throwing off carbonic acid and leaving a lime possessing all the requisites for beet juice epuration are given in the following table:

* J. d. f. d. s., 17, No. 38, 1878.

COMPOSITION OF EUROPEAN LIMESTONES.

| Constituents. | French (A). | Belgian (B). | Austrian (C). | German (D). | French Marls (E). |
|---|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Calcium carbonate | 99.10 | 99.00 | 97.49 | 98.28 | 81.80 |
| Water | 0.11 | 0.20 | .... | 0.15 | 16.83 |
| Organic substances | 0.15 | 0.10 | | | |
| Organic insoluble substances and silica | 0.27 } 0.03 } | 0.40 | 1.72 | 1.14 | 0.50 |
| Ferric oxide and alumina | .... | 0.20 | 0.20 | 0.30 | 0.50 |
| Magnesia (carbonate) | .... | .... | 0.59 | 0.10 | |
| Alkalies | | | | | |
| Losses and not estimated | 0.34 | 0.10 | .... | .... | 0.37 |
| Lime sulphate | .... | .... | traces | | |

(A) Gallois & Dupont (Bull. Ass., **9**, 137, 1891). (B) P. Morgat, La pierre à chaux en sucrerie. (C) Gawalowski (Oe.-U. Z., **18**, 423, 1889). (D) Karlson (Z. **48**, 410, 1898). (E) Collignon (Bull. Ass., **9**, 136, 1891).

**Estimation and preparation.**—The best mode for ascertaining the value of limestone for the object in view is its external appearance. Preference is given to specimens whose surface has the aspect of crystallized sugar. The quarry from which the limestone is taken is frequently traversed by veins containing numerous impurities, which affect materially the average quality of the stone. Even from the same quarry the composition of the rock may vary considerably, and numerous factory complications necessarily follow. While the average composition may remain very nearly the same the ultimate difficulties arising in the kiln are numerous and varied. Hence it is important for the chemist of the laboratory to make allowances for these changes. Classification of the rock before it is thrown into the kiln evidently promotes great uniformity in the product. These classifications should be made at the very instant that the limestone is delivered in the yards of the factory, or better still, at the quarry, the furnisher then declaring in advance the exact nature of the stone he is about to deliver.

In most cases too little care is taken in the preservation of limestone against the variations of the weather; it is simply piled up with no outer protecting wall. All factories, with very few exceptions, place the French marls under suitable sheds. They already contain considerable moisture, and if the piles are small and dry weather lasts for a few days the natural moisture is soon diminished by evaporation. Experience shows that the rock

should be broke to the size in which it is to be used in the kiln before it is piled up for the air drying, the size of the lumps depending upon numerous circumstances, such as the kind of limestone used, the size and shape of the kiln in which it is to be curned, etc. With hard stone the cooking is very satisfactory if the pieces are about the size of one's fist. On the other hand, the lumps of soft limestone may be 15 cm. in diameter.

The breaking into small regular lumps has its advantages, but is not absolutely necessary and need not be done for kilns that work with sufficient intensity. Under no circumstances should the waste from the kiln be thrown back to be burned again as it would obstruct the general working and reduce the efficiency, especially in cases of small kilns. It is important also not to make the lumps too small as the slaking is then not so readily done as with larger ones. Strange as it may seem up to the present time there has been found very little advantage in breaking the stone by mechanical means rather than by hand. Limestone broken into suitable lumps weighs about 1500 kilos per cm.

**Fuel.**—Coke is generally used for burning the lime rock in the kiln. This fuel is exceptionally advantageous owing to its purity. Very few objectionable gases are thrown off, and the ultimate carbonic acid gas is correspondingly pure. In texture the coke used for this purpose should be of only moderately open grain; if too compact its burning is difficult, if too open the reverse is the case and it soon crumbles and ceases to burn. It should contain very little foreign matter, and under normal conditions there are few elements present that the lime could carry down and introduce into the juice. On the other hand, the sulphur that coke frequently contains may be the cause of numerous complications, especially when the kiln is not working satisfactorily the sulphur is changed into a sulphuretted hydrogen, which gas when carried into the carbonatation tanks may do considerable harm.

It has recently been pointed out that coke frequently contains silicates and these will bring about the same difficulties finally as if they existed in the limestone. Numerous efforts have been made to find some satisfactory substitute for coke as a fuel in the lime kilns, or at least to combine it with some other substance that would furnish the requisite caloric. All these attempts have failed, especially with anthracite coal, for the reason that the pressure of the column of limestone almost pulverizes the coal and it stops burning.

**Other fuels than coke.**—The use of other fuel in a lime kiln than coke is not possible unless it is burned in exterior grates or in gasogenes. In the former the coke burns in special furnaces and the flames directly heat the limestone. In the case of gasogenes the solid fuel is transformed into a gaseous fuel which is burned in the kiln in immediate contact with the limestone. Although with some such arrangement any fuel may be utilized; coke is generally used for the burning. In countries where other fuel is scarce wood may be used when the kiln has exterior fire grates. In the gasogene types of lime kilns, peat, low-grade coal, compressed-coal bricks, etc., may answer the purpose.

**Preparing and handling fuel.**—Coke may be broken mechanically or by hand. To prevent it from flying in all directions when broken upon a stone a special circular holder is used, which consists of an iron ring attached to a handle. When all the coke in the interior is broken the contents are poured into a basket. Although breaking coke by mechanical means may be of advantage from a labor-saving point of view it is rarely done. The WEIDKNECHT * coke breaker has in its interior a series of hammers with flexible handles, which move with considerable velocity. The coke is projected against a side bar, the larger lumps falling again upon the hammers and the breaking continuing until the pieces are sufficiently small to pass through the bars of a steel grating. The smaller particles of coke are burned under the boilers after having been previously mixed with a suitable quantity of coal. They would not burn without some such admixture, and therefore could not be used in the lime kiln. Advantages are found in weighing the coke to be used rather than considering its volume which is always misleading. Although the cubic meter is supposed to weigh 500 kilos this is not reliable as the weight varies with so many conditions.

MALANDER recommends that the breaking be done only a short time before using because small pieces of coke appear to lose a portion of their caloric power after keeping. This is true of any coke after being kept for months, hence it is a mistake to lay in a large supply, rather purchase in reasonable quantities as the campaign progresses.

The coke and limestone must be raised to the top of the kiln and emptied into the feeding hopper. In small factories a windlass and basket carrier answers the purpose, but in extensive sugar

* Bull. Ass., 7, 84, 1889.

plants hoists must be used. In some special cases bucket-band carriers may answer, but they are soon worn out and the expense of renewal in the long run involves greater expense than a well-arranged lift. In most cases the coke * or limestone is loaded in DECAUVILLE cars, run onto one of the platforms of the lift and raised to the top of the kiln.

**Types of lime kilns.**—Lime kilns are of three important types: 1. Those in which the limestone and coke are mixed. 2. Those having a lateral hearth, heating the rock by direct flame. 3. Kilns heating by a gazogene.

* **The quantity of fuel needed.**—LÉGIER [1] calculates the minimum quantity of coke needed for the dissociation of the lime rock in the following manner: It is supposed that 1 kilo of coke burning in the air will throw out 2700 calories and that it burns in a minimum of air, that is to say, in 7.5 cms. The following composition of the limestone is taken as a basis for these calculations: Calcic carbonate 90 per cent, moisture 8 per cent, impurities 2 per cent. Composition of coke: carbon 87.5 per cent, and ash 12.5 per cent.

It is supposed that the burning is accomplished at 900° C., the specific heat of the calcic carbonate is 0.21587, and that of the watery vapor 0.3337. For the dissociation of the lime rock there are needed 21.7 calories per kilo.

Water to evaporate from 15° to 100° C. demands per kilo 537+(100−15) =622 calories; one kilo of water in the form of steam, to pass from 100° to 900°, demands $\frac{800}{3}$ or 266 calories. Consequently the total needed is 622+266=888 calories. The lime carbonate to pass from 15° to 900° demands (900−15) 0.21587=191 calories. But this dissociation absorbs per kilo 21.7 kilos, and 1 kilo of lime carbonate in order to attain 900° C. consequently demands 191+21.7=212.7 calories. Taking into consideration the composition of the calories given above it is seen that in order to attain 900° 100 kilos of limestone would require the following number of calories:

| | | |
|---|---|---|
| 90 kilos of limestone | 19,143 | calories |
| 8 " water | 7,104 | " |
| 2 " impurities | 382 | " |
| Total | 26,629 | calories |

That is 9.86 kilos of coke containing 12.5 per cent ash, burning in a minimum quantity of air. This data is only given to show how the calculation should be made. MALANDER points out (1) that the caloric power of coke is higher than that used in these calculations; (2) that the limestone as now used in kilns contains much less than 8 per cent of moisture; (3) that the temperature necessary for the burning is much higher than 900° C., and (4) that the theoretical number of kilos of coke needed to burn the amount of limestone in question is much less than the 9.86 given by the calculations. Even in practice the working of a Belgian kiln requires only from 9 to 11 kilos, and some even go so far as to declare that this has been reduced to 7 or 7.5 kilos.

[1] Bull. Ass., 7, 391, 1890.

**Kilns with limestone and coke.**—The early types of lime kilns (Fig. 160) were simply truncated cones. They were built entirely of stone with a fire-brick lining and around the kiln there were three doors for the removal of the burned lime. The quicklime was held back by a suitable grating through which circulated the

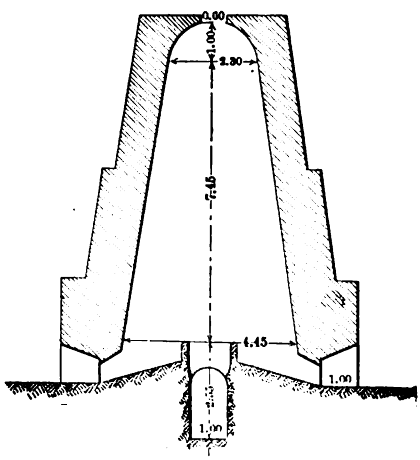

FIG. 160.—Early Type of Lime Kiln.

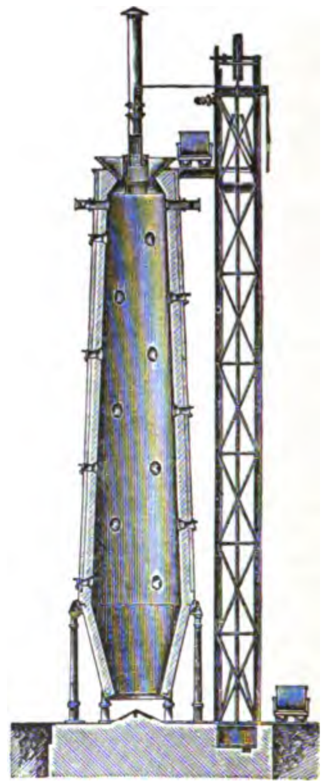

FIG. 161.—KERN Lime Kiln.

air necessary for combustion. In some cases a special central grating facilitated the air circulation and at the same time permitted the removal of the cinders and broken bits of rock. This early mode of building is now nearly obsolete, and instead a kiln called "Four Belge" of the KERN model (Fig. 161) has found much favor. The diameter is much smaller than that of any of the other kilns and its forced working secures a considerable efficiency. This kiln consists of two truncated cones placed one over the other upon their larger ends and suspended in an outer iron casing about

60 cm. above the ground. The open space beneath the kiln permits the easy removal of the lime. The outer iron casing consists of sheet iron, and between it and the refractory brick lining there is an open space filled with ashes which form a non-conducting layer. Six outside brackets rest upon six cast-iron columns. The kiln is thus well suspended above the ground and directly beneath it upon the ground is a conical-shaped distributor. The cooked lime falling upon this readily finds its way out and is within easy reach of the kiln man. The natural tendency of the cooked lime is to fall vertically through the bottom opening, but the distributor prevents this as soon as the first lumps have made their escape. These kilns for lime rock mixed with coke work only with that fuel, although experience apparently shows that anthracite coal gives very unsatisfactory results some recent experiments seem to prove that there may be a possibility of using it. Argue as one may, the use of coal will always generate not only smoke but also some tar products which are undesirable.

ALTHOFF * adopts the plan of forcing the carbonic acid gas through a small coke oven, in order to oxidate all tar substances, and thus averts all danger of reducing the purity of the juice with which this gas subsequently comes in contact. All objectionable portions are burned, owing to the excess of air contained in the gas, and under such conditions the latter is thoroughly epurated and no longer contains elements that would in any way affect the purity of the juice.

**Kilns with exterior hearths.**—These consist of a large truncated cone *A* resting upon an inverted truncated cone *B* (Fig. 162). There is an exterior iron casing with an open space between it and the refractory brick which, as in the Belgian kiln, is filled with ashes. There are three fire grates *F* for burning coke, the flames from which pass through the flues *E* and the burned lime is removed through the three doors *G*. The inclination given to the bottom facilitates the removal of the lime after cooking. The resulting carbonic acid gas is drawn off through *H* and the kiln is filled at *I*.

**Kilns with gasogene hearths.**—This type of kiln was introduced into the sugar industry by SIEMENS.† In the NEUMANN type (Fig. 163) there are four gasogene hearths *C* which are symmetrically arranged around the kiln. The inner refractory lining

* D. Z. I., 27, 1430, 1902. † Z., 14, 426, 1864.

is thicker at the bottom than at the top. The outer iron casing prevents air from entering through any cracks. The gases from hearths circulate through several flues and then find their way through $B$ to the limestone contained in the kiln. The air needed for the transformation of the carbon monoxide into carbonic acid enters through the openings $D$ from which the burned lime is

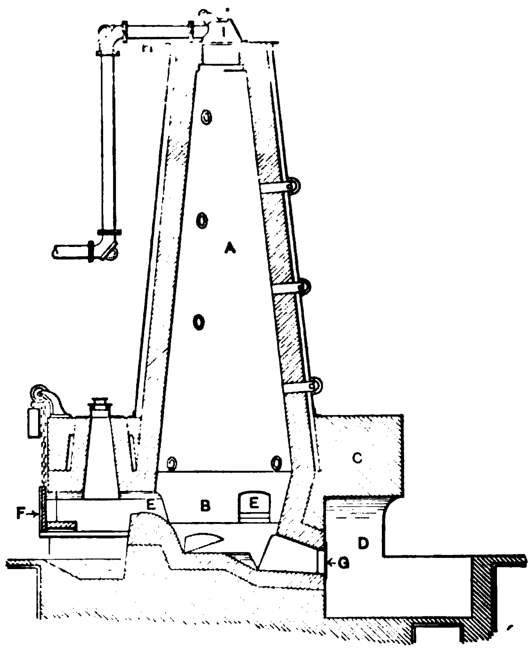


FIG. 162.—Lime Kiln with Exterior Hearths.

subsequently removed. The activity of the combustion in the gasogene is regulated by a door placed in front of the iron ash pit, and during the burning water is thrown on the hot ashes, the vapors from which keep the grate bars cool and otherwise increase the efficiency of the apparatus.

The KULMIZ gasogene (Fig. 164) is another excellent type, giving satisfactory results in lime burning. Its working is exactly the same as that of the NEUMANN type. It has three gasogene hearths $b$ which distribute their gases into $C$ through a series of complicated flues. The burned lime is taken from the kiln at the opening $d$ which is closed by a well-arranged plate $e$ during the kilns' working. The activity of the gasogene is regulated by the opening $a$.

**The shape** of a lime kiln is of more importance than is generally supposed. The greater its height the better will be the combustion of the coke. On the other hand, there is an objectionable feature to these high kilns, which is that the limestone tends to

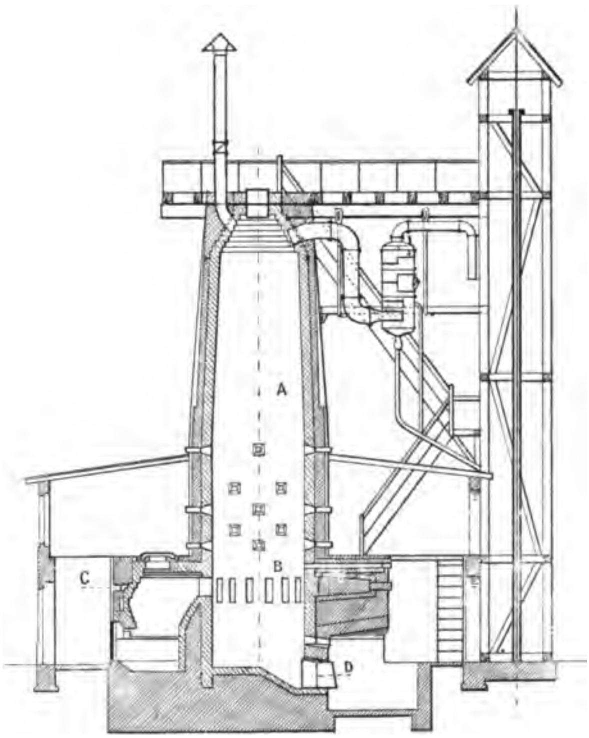


FIG. 163.—NEUMANN Kiln with Gasogene.

form an arch and remain suspended, so that there is necessarily a limit to the height determined in practice which is never exceeded.

Among the departures from standard types of kilns may be mentioned that of DECLUY,* in which the diameter is much smaller at the portion where the temperature is highest, resulting in the shape shown in Fig. 168. It is generally admitted that the Belgian lime kiln has a minimum height of 10 meters, as with a less height the fuel is not satisfactorily burned. In special cases the kilns have reached a height of 20 meters, but then the objection arises that the lime rock is crushed under its own weight. When

* La. S. B., 25, 55, 1896.

the factory requires very large amounts of lime and carbonic acid it is better to have two kilns of moderate size rather than to attempt to produce them in one kiln. In most cases no effort is made to obtain from a lime kiln its maximum efficiency, and in emergencies the Belgian kiln can render excellent and exceptional services.

Its small diameter and comparatively great height allow of far

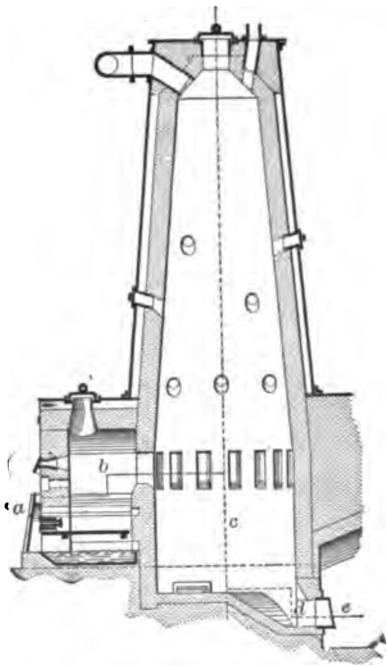


FIG. 164.—KULMIZ Kiln with Gasogene.

better combustion than can be realized with kilns which are lower and have a greater diameter.

Experience shows that lime kilns with lateral hearths are faulty in their working, and when they are of a certain dimension the limestone in their centre is not sufficiently burned. By making the kilns oval in shape this difficulty is in measure overcome. The circular section offers other objectionable features. It is claimed that with the oval-section kilns it is possible to burn lignite and obtain very satisfactory results. It is then possible to burn 12,000 kilos of limestone per diem.*

* Z., 51, 387, 1901.

**Capacity and yield.**—The capacity of the lime kiln depends primarily upon the quantity of lime to be obtained in 24 hours. If the limestone may be purchased at a reasonable price and the burning done at the factory the size of the kiln should be sufficient to furnish all the lime and carbonic acid needed for defecation and carbonatation. About one-half of the carbonic acid liberated comes from the fuel and the rest from the limestone; on the other hand two-thirds of the carbonic acid gas introduced into the juice during carbonatation is utilized. One may saturate with carbonic acid produced in the lime kiln about one-third more lime than the kiln can furnish, and this additional amount may, if necessary, be purchased.

The size of a lime kiln is also regulated by the degree of activity of its working, and consequently upon the capacity of the gas pump. The Belgian lime kiln will readily yield 500 kilos of burned lime per diem and per cubic meter capacity, and as there are needed about 3 kilos of lime per 100 kilos of beets sliced, a factory slicing 100 tons per diem the capacity should be about 6 cms. Numerous designs of kilns have been tried, but comparatively few of them have ever given the results expected.

**Increasing the size of existing kilns.**—When the factories were first built the lime kilns were always much larger than the immediate necessity demanded, but as the working capacity of the plants was increased the kilns were no longer of sufficient size to meet the requirements. In most cases there was an urgent demand for a new kiln involving a great money outlay. There is a rational solution of this difficulty which permits the kilns of an old design to be brought effectively into use, and the alteration required need cost but a few hundred dollars. Prior to the alteration the capacity of a certain kiln was 70 cm., sufficient for 350 tons of beets per diem. It had four inclined planes with four exit openings. At the centre there was a hole for the removal of ashes. The newly transformed kiln is shown in the sectional drawing herewith (Fig. 165, compare with Fig. 160).

Underneath the kiln a large cone is built of stone of a shape the reverse of that previously existing. Around the kiln is a circular open gallery for the discharge of quicklime. The generatrix of the cone should form an angle of 60° with the ground so that the burned lime slides down with regularity. The general plan adopted is very much the same as that of a high furnace used in the manufacture of iron. The kiln capacity is thus increased 25 per

cent, and a kiln that was previously 70 cm. has now become 88 cm. A kiln of this kind is very readily managed.

This transformation may be effected at a very small money outlay. The Belgian kilns may have their capacity increased without in any way changing the foundations. The kiln is taken apart at the junction of the two conical portions and the upper truncated cone is raised to a height meeting the requirements of each special case. Between the raised and the lower sections and still resting on the iron columns the refractory brick lining is built up forming a junction, or the lower inside inclination is continued and at a certain height the upper inclination is built out to meet it.

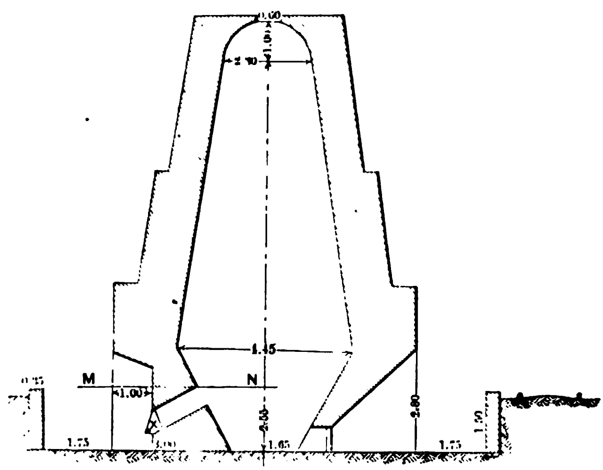


FIG. 165.—Vertical Section of a Transformed Lime Kiln.

If when there is a demand for an increase in the capacity the height of the kiln cannot be changed then the diameter is increased. In case of the gasogene attachments the height of the kiln is increased if possible in order to obtain the desired increased capacity.

**Details of construction.**—The inner lining of lime kilns consists of refractory bricks held together by a refractory cement which may be prepared by mixing 5 parts of ground refractory stone and 1 part of dried clay. The thickness of this lining should not be less than 30 to 40 cm. According to RASSMUS * the lining of lime kilns should consist of schist containing 94 per cent of silica, under which conditions the kiln will last longer and give better results. Precaution, however, must be taken not to compress

* Z., 51, 246, 1901.

the isolating layer between the silica compound and the exterior, as the dilatation that always follows would force crevices in the kiln proper.

The outer covering for the fire-brick lining may be stone or iron. The principal object in view is to keep out the exterior air which would evidently dilute the carbonic acid. If cracks are formed they should be closed at once on the outside with clay and on the inside with a refractory cement after the campaign has ended. The top closing hopper is generally conical with a regulating device which permits the coke and limestone to be equally distributed. During the working of the kiln the top is closed and the gases formed are drawn off by a special carbonic acid gas pump. The chimney on top is used only for the firing of the kiln and all connection with the exterior ceases as soon as the gas pump is set in motion. The gases are drawn from one or more upper openings which centre in a cast-iron pipe connecting with the pump. To prevent the burning from being greater on one side than on the other there should be at least two openings from which the gases may be drawn.

In most of the existing lime kilns when a soft limestone, such as chalk or some similar calcareous substance is used, certain difficulties arise, due to the moisture liberated during the process of burning. Owing to the vaporization of the water which follows the limestone used bursts into an indefinite number of small pieces which obstruct considerably the satisfactory working of the kiln. The draught is lessened and the efficiency of the appliance is naturally decreased. Attention has recently been called to the interesting arrangement of MORTGAT (Fig. 166), by means of which many of these difficulties are done away with. In the upper portion of the kiln is placed a vaporization chamber in which the limestone may slowly throw out its moisture without disintegration. In order to carry out this idea the carbonic acid is not drawn off from the top, as is generally the case, but at a much lower level, keeping the gas collector, however, on top of the kiln. In the inner surface of the kiln there is a series of openings which connect with vertical passages leading to a final outlet in the upper collecting chamber. In these the hot gases that are liberated during the operation of the burning circulate and heat the top vapor chamber the resulting watery vapor escaping through a special valve. In the drawing the gas collector openings are represented in *o*, *o′*, etc.; they unite in the upper chamber *c*;

the top of the kiln is closed by a movable cone *n*; the resulting watery vapor escapes through the valve *t* into the atmosphere or into the carbonic acid gas pipe *u*.

In the Belgian lime kiln, as before mentioned, the burned lime is readily removed from the bottom and in other existing types of kilns there are several openings for this purpose. A special bar grating prevents an excess of lime from escaping when a certain portion of the burned lime is removed. According to COSTE * the working capacity of lime kilns may be increased by simply placing at their lower extremity a movable bar grating. The cleaning above and below this grating offers no difficulty and the air finds easy access into the interior of the limestone. There results a gas very rich in carbonic acid from which oxide of carbon is entirely excluded. The combustion of this kiln is very intense and complete, combining all the essential economical requisites.

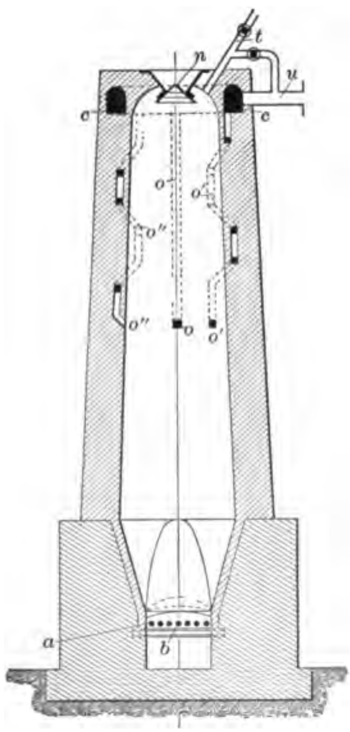

FIG. 166.—MORTGAT Kiln with Special Vaporization Chambers.

In order to withdraw the cooked lime from the kiln it becomes necessary to remove either one bar or another. The cooked stones fall to the bottom. The downward motion of the quicklime from the kiln proper depends upon the bar removed. The grate of the new design in question offers considerable advantage for starting the kiln. When these bars must have their positions changed in order to permit the cooked limestone to fall to the bottom, the fall of the product is generally very irregular and numerous complications follow. In the MORTGAT combination (Fig. 169) these iron bars have a square section *a* rounded at

* D. Z. I., **26**, 1981, 1901.

the end. They rest upon special bearings the object of which is to permit the bars to rotate on their axis. The bearings *c* are tightly held on the transverse T iron *b* (Fig. 167) by the bolts *x*. To facilitate the falling of the lime the square bars are made to rotate by means of a wrench which may be movable or fixed.

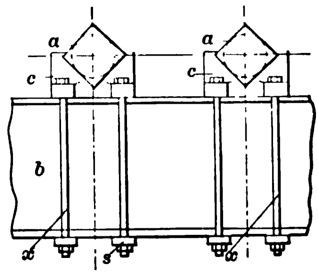

FIG. 167.—Detail of Square Gratebar Bearings.

**Cooking of limestone.**—*Action of heat.*—The cooking of limestone is simply a dissociation of the calcic carbonate, the decomposition being effected at a temperature which depends upon the physical texture and composition of the rock used. Upon general principles it may be said that the greater the impurities the rock contains the easier is its disintegration. In the case of pure stone the particles are not so readily separated. The tighter the grain the greater the difficulty of cooking. In case the limestone contains a heavy percentage of silicate combined with alumina and ferric oxide it soon breaks up when brought in contact with a reasonably high temperature. The slaking of this lime offers certain difficulties, and it does not appear to be immediately influenced by the water added. The temperature of the kiln is a very important item and it rests with the kiln man to determine by experience what this should be for the various cases that he may have to handle. The decomposition of limestone takes place at a temperature that may vary from 1000° to 1300° C. Under certain exceptional conditions this decomposition may take place at much lower temperatures if the carbonic acid gas generated is immediately drawn off. In the vacuum medium, for example, the dissociation may be effected at a comparatively low temperature, but when the degree of vacuum is lessened and the medium comparatively cooled there is then a tendency for the carbonic acid gas to be reabsorbed. At ordinary temperatures lime does not absorb carbonic acid;* it is only at 360° C. that this phenomenon manifests itself, and this tendency increases up to a certain limit, after which lime will entirely decompose under the influence of the atmospheric pressure. ERDMANN and MARCHAND claim that the

* Z., 47, 823, 1897.

decomposition commences at 400° C.; but HERZFELD'S experiments tend to show that limestone will entirely decompose when it is kept for several hours at a temperature of from 900° to 950° C. On the other hand, when burned under regular and practical conditions in a lime kiln the stone is in an atmosphere of carbonic acid and its decomposition is not completed until the temperature is higher than 1040° C., when all the carbonic acid will be liberated. A still greater heat is held necessary, for there would otherwise be danger of the reabsorption of the gas.* It is frequently argued that the so-called dead lime, or that which is not readily slaked, is due to overheating; but the facts appear to prove the contrary, i.e., that too low a temperature has caused a reabsorption of the carbonic acid. Consequently it is important that the liberated gas be drawn from the lime kiln as rapidly as possible. As previously explained, the temperature must be kept at about 1040° C., varying, however, with the nature of the rock being burned.

For practical working burning in a kiln for several hours at a temperature slightly higher than 1000° gives very satisfactory results with any limestone. The maximum temperatures that have been thus far recorded are 1200° to 1350° C., which is sufficient to properly cook any limestone even when the lumps are of exceptional size. Higher temperatures should be avoided, especially if the burning is to last for any length of time. As the product leaves the kiln it is in a superheated condition and cannot be entirely slaked unless it remains in contact with water for several days. The same transformations occur in the presence of silica, even at lower temperatures.

CLAASSEN says that a pure limestone may be entirely burned at a temperature of 1600° C. in 5 to 6 hours. HERZFELD'S experiments show that a pure lime may be melted † at from 1600° to 1650° C. Impure limestone may be melted at very much lower temperatures. Even the pure carbonate undergoes numerous transformations when kept for a long time at temperatures much lower than its melting point. Other laboratory experiments ‡ show that the pure carbonate of lime heated for 8 days at a temperature of 1200° to 1400° C. will subsequently not readily slake. Only in exceptional cases, however, does lime remain in the kiln for such a long time. In other experiments by CLAASSEN § limestone in lumps of various

* D. Z. I., **23**, 1259, 1898.
† Z., **47**, 830, 1897.
‡ Z., **47**, 830, 1897.
§ Z., **47**, 219, 1897.

sizes was thrown into a kiln, burned and taken out in one case after 16 and in the other case not until after 260 hours. On an average lime rock remains in the kiln for 48 hours and in the zone of intense heat for only a few hours.

For years past it has been noticed that the hygroscopic condition of the limestone is an important factor in the liberating of the carbonic-acid gas. It was suggested that this theory be practically utilized, and kilns were constructed so as to permit the injection of watery vapor, but none of these combinations lived long and most of them have now become obsolete. And without doubt, as HERZFELD * points out, watery vapor was a serious obstacle rather than an assistance in dissociation, especially when the lime rock was not up to the standard of purity. The temperature of cooking could be lowered 200° C., but the resulting quicklime obtained could not be readily slaked.

**Theory of the lime kiln.**—DECLUY † (Fig. 168) points out that when lime kilns are in full activity, there are several characteristic zones: (1) The regulating zone which should be kept empty so as to have sufficient volume of air to regulate the suction of the gas pump. (2) The heating zone where the limestone is heated by the gases formed during combustion of the coke and the burning of the lime rock, which at first undergoes drying and then gradually rises in temperature, while the gases with which it is in contact are cooled. In some beet-sugar factories it is customary to raise this heating zone to the top of the kiln so as to more thoroughly cool the gases and better utilize the heat. Under these conditions there is no regulating zone. (3) The combination of the coke and the cooking of the lime rock occurs in the zone of dissociation. (4) The cooling of the burned lime is accomplished in the last zone before the product is removed from the kiln. As the air coming in contact with it is heated, a fuel economy for the third zone results.

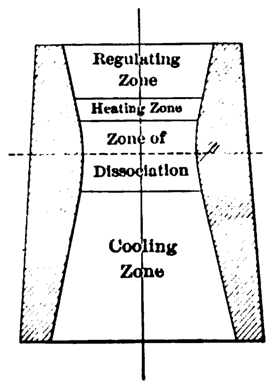


FIG. 168—Zones of Kiln.

The zone of combustion should permit the saturated hot gases

* Z., 47, 890, 1897.  † La. S. B., 25, 55, 1896.

to cool sufficiently when coming in contact with the limestone which is above, and at the same time transmit sufficient caloric for its preliminary heating. In the Belgian kilns the zone of combustion or dissociation is sometimes too high and frequently it is too low. The same may be said of the cooling zone under the zone of combustion. This should be sufficiently large to permit the drawing of the lime from the kiln in a cooled condition.

The air entering the kiln consists of oxygen, nitrogen, and traces of watery vapor. The oxygen burns the coke, generates sufficient heat for the lime cooking, and liberates the carbonic acid. This gas is also formed by the combination of oxygen and the carbon of the coke. The carbonic-acid gas coming in contact with the incandescent coke during its circulation through the limestone has a tendency to form a carbon monoxide if the air is not in excess. If this newly formed gas comes in contact with oxygen it will burn and throw off carbonic acid. At that part of the kiln, however, the air in question does not exist, and as a consequence the oxide of carbon is drawn off by the gas pump with carbonic acid. The watery vapor is decomposed in contact with the incandescent coke into hydrogen and oxygen, which forms with the carbon of the coke a monoxide. These transformations depend upon the oxygen present. A lime kiln under normal conditions should contain an excess of oxygen, watery vapor, carbonic-acid gas, and nitrogen, to which may be added in abnormal conditions hydrogen and oxide of carbon.

These chemical changes are somewhat different in the case of a gasogene, and it is to be noted that the results obtained are very nearly what theory calls for in order to obtain the maximum amount of carbonic-acid gas. One is obliged, however, to introduce into the interior of the kiln a supplementary volume of air to burn the oxide of carbon, hydrogen, and hydrocarbons generated by the gasogene, the additional oxygen amounting to from 2 to 3 per cent. This method consists in introducing a certain quantity of watery vapor through the fuel on the hearth of the gasogene, and in contact with this water the incandescent carbon is transformed into monoxide of carbon, the hydrogen of the water is liberated, and at the same time a portion of the carbon combines with the hydrogen to form a combustible hydrocarbon. All the gases which are the outcome of these reactions will burn and furnish caloric in the kiln. The additional air that enters through the openings from which the burned lime is drawn off assists in these

chemical transformations which complete the dissociation of the limestone.

**Firing a lime kiln.**—The kiln is in full activity four hours after the firing, but in order to obtain sufficient lime for the epuration of the beet juices, the firing must be done at least 24 hours before the beet-sugar campaign actually begins. After a kiln has been used for a term of years certain precautionary measures should be taken for its lighting, as otherwise there is always danger of cracks being formed in the stone work. For firing a Belgian kiln it is recommended that the outer space at the bottom of the kiln be closed with large lumps of limestone, the ring thus formed preventing the first fuel added from sliding out, and at the same time allowing sufficient air to circulate in the kiln. About 1 cm. of small sticks, etc., is thrown in from the top of the kiln, upon which 10 liters of petroleum are sprinkled, 100 to 200 kilos of coke are thrown over this, and then the coke and limestone are piled in, constantly increasing the proportion of lime rock and decreasing the quantity of coke. When the kiln is half full the fire is lighted, and then the normal weights of limestone and coke are added. The resulting smoke is allowed to escape from an upper draught chimney, and when the smoking has subsided the chimney is closed and the gas pump is slowly set to work. As long as the interior of the kiln is comparatively cool the pump requires considerable supervision and reaches its full activity only when the kiln has attained its greatest efficiency. Before that time the heat has gradually risen, and when reaching about the centre of the kiln a certain quantity of burned limestone is drawn off so that the maximum temperature is always kept at about the same height.

The firing of a kiln having several exterior hearths and fire grates does not differ materially from the same operation in a Belgian kiln. But as soon as the fire has reached the middle portion, located just above the flues of the hearths, the latter are lighted and the gas pump is set to work. The level of the fires on the hearths is from 12 to 15 cm. These are kept up constantly. Precautions should be taken not to make too many lime charges so as to lessen certain complications which at first necessarily arise in connection with the introduction of the air. The hot air from the hearths passing from the flues on to the coke promotes its combustion. The air circulation is regulated by a suitable opening which, as previously explained, is placed beneath the fire grate and

is simply a sliding door connecting with the ash pit. As this type of kiln is rapidly becoming obsolete further description of it is unnecessary.

On the other hand, the firing of the *gasogene kiln* is of exceptional interest. The first phase of the firing is the same as for the other kilns. When the temperature of red heat is attained in its interior the gasogenes are lighted and the gas pump is set in motion. Upon the fire grates considerable fuel is necessary. The kiln is then filled up to about two-thirds of its capacity and certain tests made before the volume of air entering can be properly regulated.

The chemical changes taking place in this case differ somewhat from those described in discussing the theory of the lime kiln, for the reason that the air which enters the gasogene is transformed into monoxide of carbon. Upon passing through the thick layer of fuel on the hearth it is first transformed into carbonic-acid gas by combining with the carbon, and as it makes further progress through the burning mass and reaches the incandescent portion it is transformed into monoxide. The importance of the thickness of the layer of fuel under these circumstances is self-evident. After circulating through the flues the gas is burned on coming in contact with the limestone of the kiln. The thickness of the layer of fuel in question depends upon the kind used, and cannot reach a height greater than 40 cm. The introduction of water into the fuel on the hearth of the gasogene may be accomplished in several different ways; sometimes steam is injected from underneath the fire grate, or again the iron ash pit is filled with water which soon evaporates through the action of the radiating heat. This method has the advantage of cooling the bars of the fire grate. The gasogene hearth is kept well covered by loading in the fuel through a hopper which communicates with the outside and may be hermetically closed.

The fire grates of the gasogenes connected with lime kilns are of very varied construction. There are certain types having special blowing appliances by means of which air is injected; but a serious objection to this method is that the pressure in the interior of the kiln finally becomes greater than the atmospheric pressure, which increases the tendency of the carbonic-acid gas to escape through any crack in the walls of the kiln. When the pressure on the interior is greater than that on the exterior, the dissociation of the limestone is thus obstructed.

Another very objectionable feature of these gasogenes is the

clogging of the fire grate, but this may be overcome in many different ways. Sometimes grates with rotating bars are used, like those employed for removing the burned lime from the kiln; sometimes a single bar, which may be removed and replaced, answers the purpose. The working of the fire grates may be watched through peep holes placed in the sides of the filling hopper, and when the air drawn in by the gas pump is seen to burn with a blue flame everything is progressing satisfactorily.

**Management of a lime kiln.**—Comparatively few among those who attempt to run a lime kiln thoroughly understand its management. Numerous devices have been proposed to satisfactorily accomplish the object in view, but most of them have not the least practical value. As early as 1876 BARBET * pointed out that most of the complications which arise in running a lime kiln originate in the faulty management of the gas pump. The regulation of the kiln depends upon drawing off the gas and extracting the resulting lime. To this must be added the consideration of the important rôle played by the fuel, but as the quantity used is comparatively small its influence is secondary. By proper regulation it is possible to keep the maximum heat in the zone of the kiln where its efficiency is the greatest.

The greater the volume of gas drawn off the more intense will the combustion be in the kiln and the thicker the layer of limestone which will be submitted to the temperature of 1200° and more. The more intense the kiln's working is the greater will be its efficiency in lime burning and carbonic-acid gas generation, while the consumption of fuel proportionately decreases. The zone of maximum temperature increases with the height of the kiln and the reduction of its diameter. Under no circumstances should the height of the kiln be less than 10 meters, and with this as a standard the diameter may be calculated so as to give a capacity which will furnish the necessary amount of gas and lime.

Experience seems to show that the zone where the burning is actually accomplished does not extend much beyond one-third of the total height of the kiln. The resulting carbonic-acid gas gradually heats the limestone thrown in on top of the kiln and undergoes a certain cooling. Evidently from an economic standpoint it is desirable that the gas and the burned lime carry from the kiln the smallest possible number of calories. It is customary in most

* J. d. f. d. s., 17, No. 38, 1876.

factories to mix the coke and lumps of limestone before they are thrown into the kiln, but in some exceptional cases it has been claimed that it is better to alternate the layers of limestone and coke. This mode offers many objectionable features, among which may be mentioned that during the cooking the lime tends to form an arch, and consequently pushes up the layer of coke in the centre and forces it against the inner sides of the kiln where the ultimate temperature is necessarily greater than in the middle, with the result that the limestone in the centre of the kiln is not as well burned as on the sides.

The kiln may be filled to the top, which practice is to be recommended, as the gases upon coming in contact with lime rock that is cold will yield up a portion of their caloric and be so much the cooler upon entering the gas pump. The kiln should be filled and the burned lime removed at regular intervals. The cooked lime should be removed at least every three or four hours, otherwise, as previously pointed out, the zones of the kiln would all change their positions. In certain factories it is removed every hour, and this mode has its advantages as well as its disadvantages. Evidently the general motion of all parts of the kiln is the more regular, but, on the other hand, every time the top is opened air enters and causes numerous complications. Following the removal of the cooked lime the zones of the kiln necessarily drop and the kiln man should see that they rise again to their normal level before the next removal commences. The volume of gas drawn off must then be increased so as to actuate the combustion.

If the lime when taken from the kiln does not appear to be sufficiently cooked more coke must be added. If the fire rises to an abnormal level more limestone should be drawn off, and if this tendency persists the pump should be made to go slower and the volume of coke used should be lessened. During these manipulations the top of the kiln should be watched, for if the fire reaches that level the gas removed by the pump would be so hot that it would not only heat the cast-iron connecting pipe but would actually melt it. Owing to an irregularity in the factory's running it may frequently be found advantageous to lower the activity of the kiln's working. All that is necessary is to diminish the number of strokes per minute of the gas engine; the draught then being less, there follows a general cooling. There is less lime drawn off during this interval, and portions of the lime rock will not be sufficiently burned. This is always the case when

the lumps of limestone in the kiln are too big and are not submitted to sufficient heat to insure thorough cooking. It is recommended in such a case either that the activity of the gas pump be increased and more coke added, or that the interval at which the burned lime is drawn off be increased. If the temperature rises abnormally and the limestone leaves the kiln in a so-called "dead" condition, the speed of the pump and the quantity of coke added are reduced.

Experience and close observation through the peep holes placed at several elevations permit one to determine exactly how the cooking is progressing. When the temperature of the kiln is not sufficiently high, notwithstanding the coke added, this combustible does not burn well, which necessarily results in poorly cooked lime. The difficulty may be overcome by increasing the velocity of the gas pump and slightly reducing the quantity of coke. One of the best methods for following the working of a lime kiln is by repeated analysis of the carbonic-acid gas. It is most important to limit the lime production to the requirements of the factory. If sufficient carbonic acid is not produced to meet the requirements for carbonatation, MALANDER says the gas distributors are necessarily faulty, as all lime kilns generate enough carbonic-acid for this operation. Forty-five per cent of the carbonic acid gas resulting from the coke combustion could be allowed to escape and there would yet remain an ample amount for the carbonatation in view, and when such is not the case it may be admitted that the carbonatation has undoubtedly been conducted under very faulty conditions. In the most modern beet-sugar factories the loss of carbonic acid is not more than 15 per cent and sufficient gas remains to carbonate more lime than the kiln supplies. This explains why many purchase extra lime from outside rather than go to the expense of increasing the size of the kiln. Arrangements should always be made to have a few tons of quicklime in reserve before the fresh product is received from the recently started kiln, and one is then equal to any emergency that may present itself if the kiln works irregularly. But this reserve supply should be kept within reasonable limits, for, as previously mentioned, quicklime exposed for a certain period to the air will absorb moisture and carbonic acid and then lose its value as an epurating agent.

The air in the proximity of a lime kiln is more or less saturated with carbonic acid, and is a serious danger to the health of the kiln

men, especially when the kiln is placed in the interior of a building. This difficulty may in a measure be overcome by having suitable openings at the bottom of the wall, but during the winter cold air enters and the workmen often at the risk of their lives close these communications with the outside air in order to keep warm. It is most important that the workmen be made familiar with these facts, so that they will not take any chances which might endanger their health.

When the sugar campaign has terminated the gas pump is allowed to continue its working until the kiln is entirely extinguished.

**Perturbations in lime kilns.**—There are other serious difficulties to contend with in handling a lime kiln besides those just mentioned. In exceptional cases the fire of the kiln may, for some unknown reason, be extinguished in the midst of the campaign, notwithstanding the fact that the requisite coke has been added and the gas pump is doing its work in a satisfactory manner. The real cause is probably some neglect on the part of the kiln man. The kiln must, in such a case, be entirely emptied and fired in the manner already explained. The reserve lime bridges over the difficulty, and with good management the delay need last but a few hours. In this case some recommend that the gas pump be started with the first firing, but this practice is evidently a mistake, for the soot arising from the petroleum would necessarily clog the valve.

Lumps of lime stick to the inner lining of the kiln and give rise to one of the greatest and most frequent difficulties contended with. This is caused in most cases by the production of slag upon the inner lining, whereby the limestone forms an irregular arch above these portions. Frequently also the sticking is due to the temperature of the kiln having reached a point at which the lime by softening and then cooling forms a bridge or scaffold and remains in position. This should be broken by the use of long pokers introduced either from the top or through the observation holes placed in the sides. The breaking necessarily causes a delay in the entire manufacturing process, which, especially in kilns of small diameters, may amount to several hours. If it is customary to fill the kiln up to the top, the man in charge soon notices that the downward movement of the lime is obstructed, and this is especially made evident after a certain amount of burned lime has been removed and the mass of the kiln remains stationary. PROKOP-

KOWSKI * suggests that the difficulty may be overcome by increasing the velocity of the gas pump. The draught being augmented, the burning is more active, the lime softens and causes the falling in of the scaffold. From that time on the speed of the pump is lessened and a considerable portion of the contents of the kiln is removed so as to keep the mass in full activity until it reaches a point where the burned lime taken out has no longer the appearance of the "dead" product previously mentioned.

HORSIN DÉON claims that the difficulties of bridging may be overcome in a few minutes by throwing into the kiln a ball of red lead the size of the hand. This is said to combine with the silica, soften the surface, and thus accomplish the object in view. But if in spite of all efforts the lime still sticks, the kiln must be extinguished.

The refractory bricks forming the inner lining of the kiln are soon worn out, especially when the burning has to be done at exceptionally high temperature. After each campaign repairs must be made and the bricks completely renewed every four years. When, as frequently happens, one of these bricks becomes displaced or worn out, the flame from the interior will redden the outer iron casing. Special care should be taken that this exterior casing be perfectly air-tight, or made of good bricks or stone, and that the peep holes be properly protected so that no outer air can possibly enter. When lime kilns have worked for a period of years without a renewal of their fire bricks, the portion subjected to the highest temperature becomes so thin that it may fall in, which is a most unfortunate accident, as many days are then needed for repairs. Hence the importance of having on hand a good supply of these refractory bricks. If the lining is removed as soon as it is reduced to half of its original thickness, such an accident can never occur. (This refers to the removal of the portion that is exposed to the higher temperature.) After making repairs or before starting a new kiln it is evident that the precaution should be taken to light a wood fire in the interior, with the object of thoroughly drying the exposed parts. This heating should be very gradual.

**Advantages of different lime kilns.**—Of all the different models of lime kilns the type known as the Belgian gives the most satisfaction. They have no special grating and the coke is thrown in on top at the same time as the limestone. Besides this excellent kiln, the

* B. Z., 24, 478, 1900.

gasogene type with its lateral hearths has been very satisfactory. The resulting gas contains about 30 per cent of carbonic acid with an excess of 2½ per cent of oxygen. The composition of the gases from the Belgian kilns is rather better, hence it may be concluded that the combustion is more satisfactory, and, furthermore, less coke is needed to reach a given result. On the other hand, one of the great advantages of gasogene lime kilns is that low-grade fuels, such as peat, brown coal, compressed coal-dust, etc., may be burned. In the case of brown coal * 14.9 kilos are needed for 100 kilos of limestone.

The smallest possible fuel combustion is obtained with the Belgian kilns. Notwithstanding the fact that the coke used must be of fair quality, while in the gasogene combination cheaper and inferior coke may be employed, there appears to be very little difference in the practical results obtained in the two cases. This is made evident by the fact that if poor coke is combined with the limestone a certain quantity of carbon must be used to effect the dissociation by burning, and the amount needed to attain a given result is necessarily greater than when a superior fuel is used. The fault found with the Belgian kiln is that there is necessarily a mixture of ash, coke, and burned lime, but too much stress is placed on this point. In any coke the percentage of soluble ash is excessively small. As the total coke used is not more than 0.3 per cent of the weight of the beets sliced, and as most of this ash is mixed with the dust and the residue of the limestone which is not used for liming the juices, MALANDER says that the soluble ash that finds its way into the factory is insignificant in quantity and need not be considered.

**Burned lime from kiln.**—The burned lime should leave the kiln cold, but as this is never or rarely the case it must be cooled before it is used for liming, as contact with the water when hot would result in dangerous projections of particles of lime which are not to be feared when the quicklime is hydrated cold. In case the capacity of the kiln is such that it more than meets the requirements of the factory a selection of the burned lime is desirable, and only those portions that are up to the standard should be used, while the badly cooked portions are thrown aside. When the limestone has not been sufficiently burned it wears away the pumps and the valves with which it comes in contact. The poorly

* Bull. Ass., 14, 390, 1896.

burned stone may be recognized by its weight, the "dead" lime, by its physical aspect, and by dropping it upon a hard substance it gives a metallic sound. When the gas pump is not working satisfactorily, it may happen that the lime instead of being too much burned will absorb the carbonic acid. On the other hand, stone that has been properly burned is light, porous in appearance, and gives a dead sound when dropped.

**Testing lime.**—STIEPEL * says that one of the essential elements in the composition of a limestone to insure the regular working of the kiln and successful carbonatation is the oxide of calcium actually contained. A special calorimeter is used for estimating the oxide of calcium by means of the temperature generated during the combination of this oxide with water to form hydrated lime. This change liberates 1500 calories per molecule gram of the oxide of calcium. In order to eliminate a number of calculations a thermometer with a special scale graduation is used which indicates in one reading the quantity of oxide of calcium present. The apparatus consists of a cylindrical vase in ebonite, closed by a bayonet covering and pierced with two holes, through one of which is introduced the thermometer and through the other a brass bar having at its extremity a small wire basket in which the lime under examination is deposited. In the interior of the basket is a second and smaller cylindrical receptacle in ebonite, containing a glass jar which is adapted to it as exactly as possible. Underneath the second receptacle is a spiral spring which presses it against the cover. The apparatus when full contains 50 cc. of water at 15° to 25° C. The lime is placed in the basket, the entire apparatus is closed, and the movable scale of the thermometer is displaced so as to bring it to the zero point. The basket containing the lime is lowered into the water by the assistance of a rod, and is slowly but continuously agitated until there is no longer an increase of temperature, a period lasting about two minutes with lime burned under normal conditions. The exact weighed quantity of lime under examination is about 8 grams. This apparatus may also be used for the examination of limestone.

It is evident that the more important essential is that the lime kiln be so constructed as to give a thoroughly burned lime and a gas rich in carbonic acid.

**Carbonic-acid gas from the kiln.**—The gases drawn from the

* Z., 51, 897, 1901.

kiln are those formed in the combustion of the fuel and the carbonic-acid gas liberated from the limestone, and are more or less mixed with free cinders from the coal or coke. The gas mixture upon leaving the kiln has a temperature depending upon the height of the evacuation orifice; it should never rise so high that the exit pipes become red-hot. Evidently all the heat carried forward by the gas represents so much lost caloric; but by increasing the height of the regulating zone a portion of this heat may be absorbed by the limestone last thrown into the kiln and the temperature of the carbonic-acid gas withdrawn may be thus reduced to 300° C. In many factories this gas has a temperature of from 500° to 600° C., which means great waste of fuel.

Before the gas can be used for carbonatation it should be freed of all objectionable impurities and properly cooled. For this purpose a mechanical epuration, by means of an apparatus known as a washer, is sufficient. Beside carbonic acid the gases contain nitrogen and small quantities of oxygen, also oxide of carbon and sulphurous acid, which constituents have no pernicious action upon the juices; on the contrary, the latter has a slight epurating effect. The monoxide of carbon contained in the carbonic-acid gas represents a loss of fuel and furthermore is a violent toxic, but according to BARBET * exerts no objectionable influence upon beet juices.

These compounds consequently need not be eliminated. The sulphuretted hydrogen that is produced in the kiln when there is not sufficient air may have an objectionable action upon the juices, but its generation can be entirely prevented by giving due care to the details of conducting the lime kiln. To this end the size of the zone of dissociation should be kept within reasonable limits and the coke thrown in should not be allowed to pile up. These precautions are alone sufficient to enable one to dispense with appliances intended to absorb the sulphuretted hydrogen.

**Control and composition of gases.**—In the control of a lime kiln the carbonic-acid gas should be repeatedly analyzed, and special care given to the fuel used and the amount of monoxide of carbon and oxygen present. Of the first mentioned none should be found in the gas drawn from the kiln, but of the second there is always a certain quantity, 2 to 3 per cent being considered normal. During its passage through the kiln the oxygen carries with it a considerable number of calories. If this excess of air is from leaks at

* J. d. f. d. s., 17, No. 38, 1876.

the kiln top, it does not carry with it much heat, but does cause a considerable dilution of the carbonic-acid gas and decreases the efficiency of the gas pump.

CLAASSEN in discussing the amount of carbonic acid present in the gas used during carbonatation says that it depends upon the facility with which the gas was generated in the kiln, that is to say, the smaller the amount of fuel and air used in burning the limestone the richer the resulting gas will be. It is possible under the most favorable circumstances to draw from a lime kiln, in which the lime was burned with 10 per cent of coke, a gas containing 37 per cent in volume of carbonic acid, while with a consumption of 12 per cent of coke under similar circumstances one obtains only 35 per cent of carbonic-acid gas. In many lime kilns the gases obtained have a content of from 30 to 35 per cent; but this percentage fluctuates because the production of gas is always greater after the filling of the kiln than it is later. Generally 20 to 30 per cent of carbonic acid in the gases obtained in kilns with gasogene attachments is sufficient for practical purposes. It is frequently argued that a gas very rich in carbonic acid will carbonate more slowly than one which contains only 25 or 30 per cent. From practical tests this appears to be true, but in theory it is not justifiable. When it is desired to obtain gases containing a comparatively low percentage of carbonic acid, an excess of air should not be allowed to enter the kiln, but should be introduced into the gas before it enters the carbonatation tanks.

A carbonic-acid register of a new design* to be attached to a lime kiln consists of two tubes, 1.75 meters in height, one of which is full of air and communicates with the upper tube of an inclined micro-metric manometer. The second tube runs through the gases of the lime kiln and communicates with the other tube of the manometer. The difference of pressure forces blackened alcohol to rise in the inclined tube of the apparatus. A special table or scale permits one to ascertain in one reading the carbonic-acid percentage of the gases that are being thrown off by the kiln. A well-arranged metallic reflector projects light through the liquor that is colorless upon a photographic slip which is in constant motion. An impression is made in the dark chamber acting as a camera and the length of the wave line indicates on a continuous diagram the carbonic-acid percentage.

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* C., 9, 830, 1901.

**Piping connection between kiln and gas pump.**—The gases on leaving the kiln escape from an upper pipe. In many kilns there are two openings, one opposite the other, so that the gases in their circulation through the mass of limestone do not always follow the same direction. These exit pipes join outside the kiln. As the carbonic-acid gas generated in the kiln is frequently very hot on reaching the exit orifice, it increases in volume and requires pipes of considerabe diameter for its free circulation. It sometimes happens that these pipes become clogged by deposit of coke, dust, etc., and for the removal of such obstructions a movable cover is generally placed at each bend of the pipe. The gases on their way to the pump pass through a washer.

**Gas washing.**—The principal rôle of the washer is to cool the gases and free them from particles of cinders in suspension and other products which are the outcome of the fuel combustion. The washers may be cylindrical reservoirs of iron, wood, stone, or brick, cemented. As iron is frequently attacked by the gases preference is generally given to cemented or wooden receptacles. The washing is done under the most advantageous circumstances, according to the principles of counter currents, by allowing the water to circulate in the opposite direction to the gas, which enters at the bottom, and by using a distributing agent, such as coke. At the lower part of the washer a small quantity of water is allowed to settle by placing the overflow at 40 cm. above the bottom, and the hot gases upon entering the apparatus pass first of all through this layer of water.

A gas washer very much in vogue in Germany (Fig. 169) consists of a cast-iron column made up of a series of disks. The gases from the kiln enter the washer at the bottom, bubble through the water in which the ends of an inverted cup are submerged, and move upward where they find another inverted cup of the same kind; upon reaching the top they pass through a grating, upon which is a certain quantity of coke intended to absorb the moisture, and finally escape on top of the column. The water in this appliance circulates in the opposite direction to that of the gas. It enters through an upper pipe, fills in the spaces around the cups, overflows successively from disk to disk, as shown by the arrows, and finally escapes from the bottom overflow. The operation may be followed closely through the peep holes. The flow of water is regulated by the valve on top.

There are many designs of gas washers of more or less interest.

Sometimes they consist of a simple vertical cylinder with perforated divisions. The water circulates by drops in one direction and the gas in another. Another type of gas washer (Fig. 170), which has been used in France with considerable success for many years, is one in which the cold water is introduced at *A* and the gases enter at *E*. The water and gas circulate in opposite directions. In consequence of the suction of the pump there is a slight vacuum, and hence the escape pipe for the water should be siphon-shaped.

In some factories two gas washers of different design, one following the other, are found advantageous. Experience appears

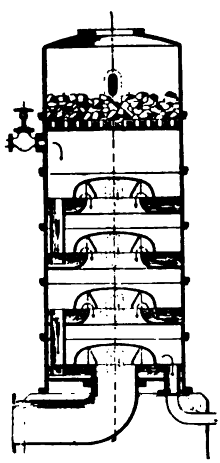

FIG. 169.—German Gas Washer.

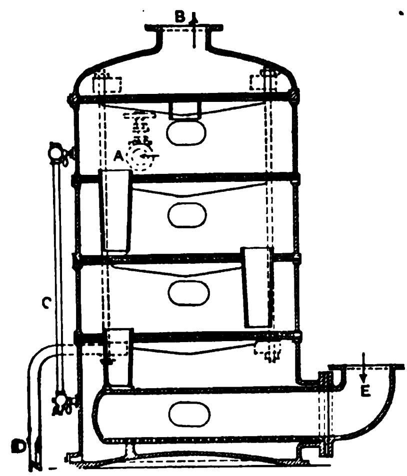


FIG. 170.—French Gas Washer.

to show that the pipe conducting the water of the washer should not have a diameter greater than 2.5 cm., otherwise too much water would circulate and the cooling of the gas would not be effected. The water upon leaving the washer should have a temperature of 30° to 40° C.; if the cooling were pushed beyond that limit considerable more water would be needed.

As water absorbs a certain amount of the carbonic acid, the volume used for this washing should be limited and its entrance so regulated that it will run hot from the overflow, under which circumstances it will absorb less gas. The gases are then well cooled, for the reason that they come constantly in contact with cold water in the upper portion of the washer. A satisfactory

cooling of the gas has its advantages, among which may be mentioned the increased efficiency of the carbonic-acid-gas pump, as the cooler the gas is the smalleri s the volume which it occupies. The water passing through the overflow at the bottom of the washer must continue downwards to a depth of at least 2 meters into a tank full of water. This column of water is to compensate for the vacuum of 0.1 to 0.2 atmosphere made in the washer by the gas pump. Without this precaution the exterior air would be drawn into the apparatus.

Among the precautionary measures necessary to attain a satisfactory working of the washer, the water used should not contain an excess of lime, as the resulting deposits would then tend to diminish to an important degree the section of the pipes; the openings through which the water circulates should be frequently examined. To increase the output of the gas pump, the friction in the piping and washer should be kept as low as possible. The gases during their circulation in the washer should not have to overcome the resistance of an excessively high column of liquid. The reduction of pressure in the suction pipe connecting with the pump cannot be less than that corresponding to a column of 1 meter of water. For the surveillance of this pressure reduction, it is recommended to connect with the front and back of the suction pipe of the washer and with the carbonic-acid gas pump vertical glass tubes plunging into water. In this way the difference of pressure at different centres is indicated and the loss of pressure in the piping and in the washer can be determined. Water oscillating in the glass tubes between the washer and the pump indicates an irregular working of the washer.

In Belgium a very simple method has been proposed for ascertaining whether any losses take place in the lime kiln. On the carbonic-gas pipes are placed several U-shaped glass tubes filled with mercury. These are located where the gas leaves the kiln: before and after the gas washer, and before and after the gas pump. If at any moment a great difference is noticed in the level of the mercury in the U tubes, the location of the difficulty can be determined at once. The expense involved is very slight, and if it is found necessary, the number of tubes may be increased, which makes it still more certain that the trouble will be localized.

In order to prevent the water carried forward by the gas during its passage through the washer from reaching the pump, a so-called water separator in the piping should be used.

**Gas injection into juices.**—The use of an injecting combination was first introduced by WALKHOFF (Fig. 171). It works on very much the same principle as a GIFFARD injector. The amount of

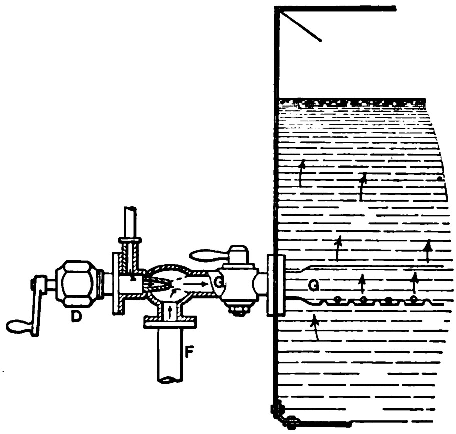


FIG. 171.—WALKHOFF Gas Injector.

steam used is regulated at *D*, and carries with it the carbonic acid gas which entered at *F*. Both the steam and gas enter the carbonatation tanks through *G*.

**Gas pumps.**—The carbonic acid gas to be used for carbonata-

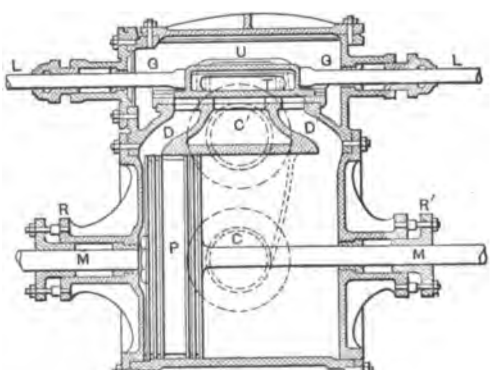


FIG. 172.—French Gas Pump (Section of Cylinder).

tion is forced into the juice by means of pumps which must be worked by direct action; they should have their own steam cylinder so that the number of revolutions may be regulated according to the amount of gas required. The steam injectors which are sometimes used for the introduction of carbonic acid gas into the

juice are not desirable for several reasons. They consume too much steam and dilute and overheat the juice unless placed before the gas washer. They are, however, able to overcome considerable counter pressure and in an emergency, such as a break down of the gas pump, these injectors may render valuable service.

The cylinder of the pump most frequently used for drawing the carbonic acid gas from the kiln and forcing it into the carbonatation tanks is shown in Fig. 172. It is put into motion by an engine which at the same time works the juice pump. This engine has an iron piston *P*. The rod secures its motion direct from a horizontal engine and is guided by *R* and *R'*. The gases of the kiln drawn off through the pipe *C'* arrive under the slide valve and pass

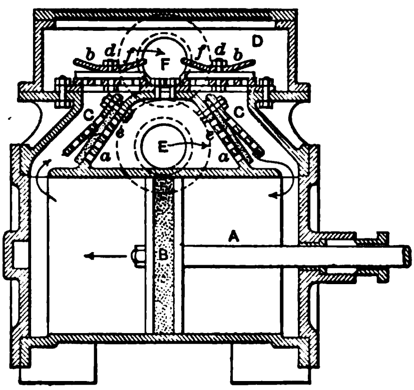


FIG. 173.—German Flap-valve Gas Pump (Section).

through *D'* behind the piston. The gas in front of the piston is forced through *D*, then into *U* and is sent through *C* into the carbonatation tanks. Water may be used as a lubricant for the valve *T*, which removes the deposits of coke, lime dust, etc., which may have been drawn forward with the gases. This demands the opening of the purge cock and a loss of carbonic acid. In modern methods of working the water lubrication has been more or less abandoned as the pumps are constructed to meet the emergency in question. The slide valves should be properly regulated so as not to open before the piston is at the end of its stroke, otherwise a certain quantity of gas drawn from the kiln would be forced back, and a part of the gas on finding its way to the bottom of the kiln would recombine with the lime to form a calcic carbonate and would be drawn from the kiln as such. Although the gas pumps with flap valves are much less used than formerly they

continue in vogue in certain parts of Germany. Their arrangement is shown in Fig. 173. The piston $B$ in this case is in a half-way position, the gases from the kiln entering at $E$, open the flap valve $a$, and enter the cylinder $A$, while those in front of the piston are pushed through $C$, raise the flap valve and escape by $F$.

As a general thing the gas pumps are worked slowly and the best practice seems to recommend a velocity of 40 meters per minute, although in exceptional cases the speed may be doubled without resulting in any complications. When the ports of the slide valve are sufficient for all needs the gases from the kiln circulate at a velocity of 15 meters per second. As the demands on the gas pump vary from hour to hour the necessary changes should be easily made, to which end an independent engine which is readily adjusted should be used.

As the gas must be forced through the juice it becomes evident that if the pump is too small or if it does not work properly, the carbonatation will never be satisfactory. The size of the pumping cylinder should always be ample, permitting the pumping to be done under normal conditions with very few revolutions of the engine, and allowing other difficulties, such as faulty joints of the valves or even the poorness of the gas, to be compensated for even by a slow action of the pump.* The quantity of gas supplied or

* The dimensions of a gas pump are calculated as follows: Assuming that the lime consumption is 7000 kilos per diem, corresponding to 13,160 kilos of limestone at 95 per cent, that the temperature of the gas on entering the pump is 50° C., and that the coke contains 90 per cent of carbon, 100 kilos of this limestone will throw out 41.8 kilos of carbonic acid and will occupy a volume of 27,152 liters at 50° C. and 700 mm. pressure. Consequently 13,160 kilos will throw out $\frac{13{,}160 \times 27{,}152}{100}$ or 3573 cu. m. of carbonic acid. Gallois[1] says that for the burning of the stone there are needed 1253 kilos of coke or 9.5 per cent of its weight. This coke demands for its complete combustion 3008 kilos of oxygen, which will bring with it 10,070 kilos of nitrogen. The 4136 kilos of carbonic acid, formed by the burning of the coke, would occupy a volume of 2687 cu. m. at 50° C., and the 10,070 kilos of nitrogen occupy 10,300 cu. m. The total volume of gas to be removed from the kiln is consequently as follows:

| | Cu. M. |
|---|---|
| Carbonic acid from the limestone | 3,573 |
| " " " " coke | 2,687 |
| Nitrogen | 10,300 |
| Total | 16,560 |

[1] Bull. Ass., 1, 220, 1883.

the efficiency of the pump is diminished when there is excessive depression in the suction pipe.

**Piping connection.**—The force pipe of gas pump connecting with the carbonatation tanks has numerous valves, including a safety valve which opens only in case all the others are closed, and is so arranged that the pumps work in such a case without difficulty. This safety valve connects with a chimney which is higher than all the others of the factory. Upon the force pipe in question there should also be placed a flap valve which opens from the outside to the inside and allows air to enter as soon as there is the slightest vacuum in the pipes. This may occur when the gas pump stops and the valve connected with the carbonatation tank remains open. Under these conditions there is always danger of the limed juice finding its way into the cylinder of the pump. The best arrangement is that in which the pipe of the force pump reaches a height at least 1 meter above the maximum level which the juice may attain in the carbonatating tank. In some factories it is customary to use a carbonic acid regulating receptacle which has a volume ten times greater than the capacity of the gas pump and is placed on the pipe carrying the carbonic acid gas.

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The theoretical richness of the gas in carbonic acid is 37.8 per cent in volume, but in practice it is not more than 25 per cent. Consequently the volume would be $\frac{16,560 \times 37.8}{25} = 25,038$ cu. m., and this must be removed by the pump every 24 hours, which is equivalent to 414 liters per second. The diameter of the piston is calculated upon the basis that the stroke is 0.83 meter per second and has a length corresponding to two-thirds of the diameter of the cylinder. In this manner the sizes may be calculated for different plants as follows:

| Tons per Diameter. | Meter Diameter. | Length of Stroke, Meter per Second. | Strokes per Minute. |
|---|---|---|---|
| 300 | 1.00 | 0.66 | 74 |
| 400 | 1.15 | 0.75 | 64 |
| 500 | 1.29 | 0.85 | 58 |
| 600 | 1.40 | 0.92 | 50 |

## CHAPTER II.

### LIMING.

**Purpose of liming.**—Green beet juices after having been heated are submitted to the action of lime, or in other words, they are defecated. The liming of beet juices is one of the important operations of beet-sugar manufacture, and if it is not effected in accordance with accepted principles all succeeding operations will be unsatisfactory and the ultimate product will not crystallize properly. Lime added to saccharine juices will prevent the objectionable action of most of the foreign substances in solution. The lime is subsequently eliminated by contact with carbonic acid, this operation being called carbonatation. A calcic carbonate is precipitated which may be separated by filtration.

**Historical data.**—The now obsolete mode of defecation was conducted in the following manner: * The juice was rapidly heated to 85° C. in double-bottom copper receptacles, then ½ a kilo of milk of lime, in the form of calcic oxide, was added for each 100 kilos of beets sliced, producing an abundant precipitate and causing considerable surface frothing. The clear liquor was decanted, the surface scums and the precipitate that had settled at the bottom being separated by bag filters, and in this manner all the particles in suspension were separated. To ascertain whether the operation had been properly conducted, special attention was paid to the aspect, color and taste of the clear juice. This mode of epuration had many objectionable features and frequently led to careless methods of working which caused numerous complications in the following operations necessary to obtain the final white sugar. As compared with the modes of liming now in vogue it offered only one advantage, namely, the small quantity of lime needed; but it was later demonstrated that the use of so small a percentage could

* Walkhoff Ruebenzucker Fab., 1, 54, 1857.

not possibly bring about the desired epurating effect. As early as 1843 SCHATTEN used lime in excess and neutralized the free alkali with carbonic acid. In 1848 ROUSSEAU * was the first to apply, at the beet-sugar factory at Flavy-le-Martel (France), a method of liming which formed the basis of the process of defecation now employed. His idea, however, was not generally adopted, and it was many years before it really came in vogue, Possoz justly receiving the credit of its popularization. The method adopted was to add 1 per cent of quicklime to cold beet juices and allow them to stand before decanting; to the clear liquor from 2 to 5 per cent more of lime were added; the carbonatation at 60° to 100° C. followed, and the carbonatated juice obtained was then filtered.† The decanting was later done away with.‡

After an interval of years the process underwent further modifications, and even greater quantities of lime were added to the juices.§ After these changes the process bore a striking resemblance to that of FREY-JELINEK. In the meantime it found numerous applications in Germany and Austria. The last mentioned process had an advantage over that of PERRIER and Possoz in the fact that it did away with the decanting after defecation and reduced the epuration of beet juices to a single operation. In the FREY-JELINEK liming 2 kilos of milk of lime in the form of calcium oxide are added for 100 kilos of beets sliced, the operation being conducted at 25° to 38° C. At first the carbonic acid was gradually introduced, then after a reasonable interval the quantity was increased, and meanwhile the juice being treated was heated at 50° to 62° C. The carbonatation was completed at 85° C. The remaining alkalinity was 0.07 per cent calcic oxide. The operation was terminated when upon examination a sample of juice was found to have the standard aspect.‖

The liming as now conducted has many of the characteristics of the JELINEK method. Combined with a suitable sulphuring, the process gives very satisfactory results and the boneblack filtration is no longer necessary. The elimination of the char was accomplished only after long years of continued discussion.

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* Z., **11**, 65, 1861.

† S. I., **35**, 1866.

‡ S. I., **1**, 52, 1866.

§ PERRIER, Possoz, Cail & Cie, p. 4, 1867.

‖ JELINEK, REINIGUNG, Prague, pp. 17 and 19, 1864.

In 1881 the Gembloux Belgium factory stopped using boneblack,* since which time its use in beet-sugar factories has almost entirely ceased; in fact, many sugar refineries are beginning to realize that it is no longer needed to obtain sugar of a superior quality. The sugar losses were lessened and the dirty manipulation of the char in the kilns and filters is becoming a past issue.

**Theory of defecation or liming.**—Twenty years ago von LIPPMANN † pointed out that while the operations of liming and carbonatation were generally adopted there appeared to be very little concern as to the whys and wherefores. While great progress has been made in this direction, without doubt much yet remains to be accomplished.

The action of lime upon raw or green juices is at the same time chemical and mechanical. Chemically the lime precipitates and decomposes the non-sugar; mechanically it carries down the substances and particles in suspension by surrounding them in the precipitate. In raw juices, particles and filaments of beets that have not been held back by the cossette arrestors are always found among the suspended substances, and also all constituents that have been precipitated by heat, and a large quantity of micro-organisms and ferments which are evidenced after a prolonged settling of the juice in an objectionable manner, as they are responsible for the sugar inversion and acidity of the juice. All these substances, as before said, are carried down by the precipitates. The scums thus formed soon settle at the bottom, while the juice forms the surface above, and is of a light yellow color, limpid and perfectly sterilized. The defecation by surface frothing which was formerly practised with press juices is impossible with juices from the diffusion battery; but, on the other hand, the latter when submitted to the action of sufficient lime are easily filtered. The chemical action of lime upon the non-sugar takes place in such a way that the lime neutralizes the free acids and the acid salts, and combines with a portion of the organic and inorganic acids, mainly oxalic and phosphoric, forming insoluble salts. The oxalate of lime is almost entirely eliminated during the working of the juice in the factory, as its solubility diminishes with an increase in the saccharine percentage and becomes zero with a concentration of 50 per cent of sugar.

Silica is almost entirely separated during liming. It comes

* LOZE et HÉLAERS, Travail sans noir, p. 52, 1884. † D. Z. I., 8, 1161, 1883.

from the water used in the diffusion battery, impurities of the limestone and earth adhering to the beets. Furthermore, all the insoluble silicates are precipitated in an alkaline calcic solution. The alkalies, ammonia, and organic bases of raw-beet juices which were combined with the precipitated acids are liberated and add their action to that of the lime in excess upon the non-sugar. The alkalies being stronger bases, combine at once with the acids, which do not form insoluble compounds with lime, while the ammonia and the organic bases remain in the juices in their free state. Many of the organic non-sugar substance remaining in solution undergo a greater or less decomposition is an alkaline solution. All these substances create acids in the hot alkaline solution, while the nitric substances at the same time form ammonia or organic bases. The acids, which with lime form only soluble salts, will first of all combine with the liberated alkalies, and those remaining combine with the lime.*

The alkaline salts of the beet are transformed into carbonates by the presence of lime in the juice, and there follows a double decomposition of the calcic salts resulting in potassic salts and calcic carbonate. This reaction depends upon the percentage of alkaline salts and if these are wanting calcic organates will be formed. The alkalies of beets cannot precipitate all these calcic salts.* Beet juices also contain calcic sulphate which is formed by the oxidation of sulphur. The sulphide of lime is not entirely insoluble and is transformed into calcic sulphate. The phosphate of lime is produced by the decomposing action of lime on the palmitate, stearate of lecithin, etc. The alkalies in raw juices are not eliminated through defecation. True, a small quantity is eliminated surrounded by the lime precipitate during carbonatation, but the greater portion remains in solution combined with the acids or as free alkalies, and is to be ultimately found in the *massecuite*. The proportion of free alkalies existing in defecated juices depends upon the acid with which these alkalies were combined in the raw juices. If the latter contain considerable acid, such as oxalic acid, which forms insoluble compounds with lime, the soluble acids remaining after defecation are not sufficient to neutralize the alkalies; a large proportion remains in a free state and exerts its influence during defecation and subsequent operations in decomposing the non-sugar. For juices

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* C., 9, 89, 1900.

which after carbonatation still contain alkali carbonates a recoil of the alkalinity during evaporation is not objectionable. One finds little or no lime. But if the acids of raw beet juices combine mainly with the lime to form soluble salts, the liberated alkalies during defecation will, either during defecation or saturation, eliminate the lime of these salts.

**Action of lime, varied opinions.**—As regards the action of lime expert views differ. Some authorities claim that lime tends to decrease the ultimate yield of sugar. According to WEISBERG * its percentage in beet juices depends not only upon the quantity used during defecation, but also on the original percentage present in the green juices. Its salts are the outcome of a double decomposition and saturation of the acids contained in the juices, and through the decomposition of the asparagine and glutamin still other lime salts are formed. In addition to these three important sources there are others too numerous to be even mentioned.

**Elimination of calcic salts.**—According to GRIMMER † calcic salts are partly eliminated from juices when lime is used in excess and basic lime salts are formed. MALANDER points out that excessively limed juices contain fewer calcic salts than those submitted to a moderate liming, and this would show that there is some truth in GRIMMER's reasoning.

**Influence of invert sugar.**—Invert sugar tends to increase the percentage of lime. According to HERSFELD ‡ 1 per cent of invert sugar will increase by 0.28 per cent the oxide of calcium contained in the ash.

**Albuminoid and pectic substances.**—WEISBERG's § experiments show that the pectic substances are precipitated and pectate of lime is formed during defecation. Carbonic acid even in excess will not decompose this pectate. The leading authorities on the beet-sugar industry have never come to any positive agreement as to the quantity of albuminoids separated during defecation. GROUVER,‖ for example, has demonstrated that lime will separate from the beet juices a maximum of 20 per cent of the albumin, and that saline substances are not eliminated through its influence, but that on the contrary certain calcic salts enter into solution.

The experiments of WENDELER¶ show that during defecation

* S. I., 38, 563, 1891.

† GRIMMER, Scheidung, p. 9, 1886.

‡ Z., 35, 1028, 1885.

§ Bull. Ass., 6, 440, 1889.

‖ Z., 12, 68, 1862.

¶ D. Z. I., 25, 729, 1900.

and carbonatation 57 per cent of the proteids are eliminated. The percentage of propectones is reduced to a greater extent than that of the pectones, as the former are first changed into the latter.

It is also declared that the protein substances only partly coagulate under the influence of heat and that lime decomposes the substances in question. Lime ultimately separates from the amide groups with formation of ammonia, forming soluble combinations with the remaining radicals. This reaction is not accomplished immediately; on the contrary, these chemical transformations are very slow, and may be said to be completed only in the triple effect during evaporation and in pan during graining, and it is undoubtedly then that the losses of alkalinity occur.

Beets when entirely matured contain only a very small percentage of albuminoids; while, on the other hand, when not ripe, there exist considerable quantities, which, when passing through the organic cells of the plant, are transformed by the enzymes into amide acids, such as asparagin, subsequently allowing their easy passage into the cellular tissue. Rotten beets contain large quantities of these substances and also a heavy percentage of invert sugar which also gives soluble calcic salts.*

As far as possible the non-sugar substances decomposible by lime should undergo their changes during defecation. But it is impossible to obtain their complete decomposition during this stage of the operation, as a certain portion decomposes slowly under the existing conditions of defecation, and if the operation lasts too long or the temperature be too high, the risk of redissolving the insoluble or precipitated non-sugar is incurred. The circumstances during evaporation are so favorable for these decompositions, as will be shown later on, that it would not be desirable to conduct the defecation under other conditions which could furthermore result in a poor saturation.

**Influence upon sugar.**—The sugar undergoes no change during defecation, nor is its percentage diminished under ordinary conditions of working. WEISBERG † points out that losses are always noticeable, but that they are due to a precipitation in the form of saccharate which remains in the defecation scums.

**Influence upon non-sugar.**—Consequently lime during defecation has an epurating action, as by the precipitation of the non-sugar it increases the purity of the juice; furthermore, it changes

* S. B., Oct. 1902. † Bull. Ass., **16**, 263, 1898.

the nature of certain parts of the non-sugar without eliminating a large amount of it. The two actions are very favorable both to the success of the defecation and to the operations that follow—the last being as essential as the first. Generally speaking the proportion of non-sugar precipitated is less than is usually claimed. RAHE * maintains that 50 per cent of the total non-sugar is eliminated during defecation and carbonatation. But CLAASSEN very justly points out that by these two operations the purity is increased only from 4 to 6 per cent; 100 parts of dry substances obtained from raw juice contain 12 to 15 parts non-sugar, and from these there is eliminated one-fourth to one-third at the most. On the other hand, the decomposing action of lime upon the substances remaining dissolved is too frequently overlooked. Through this transformation many of the substances lose certain properties which have an unfavorable action on the subsequent work, mainly upon the crystallization of sugar.

**Different modes of liming.**—The modes of liming differ in the manner in which the lime is used, in the quantity, in the period that the operation lasts, and in the degree of temperature at which the defecation is conducted. In the operation of defecation lime is used in five different forms: (1) Milk of lime; (2) quicklime in lumps; (3) quicklime in powder; (4) powdered slaked lime, and (5) saccharate of lime.

As previously mentioned milk of lime has now been used in beet-sugar manufacture for over one hundred years. For economical reasons the use of quicklime has met with considerable favor in Germany, but its use in a pulverized form is very much less in vogue. ROUSSEAU † recommended the use of powdered slaked lime fifty years ago, and POSSOZ ‡ in 1859. Its general use was popularized by von EHRENSTEIN § who claimed that it offered economical and numerous other advantages, such as the prevention of sugar losses. Notwithstanding these facts hydrated lime finds very little favor and its use is mainly confined to the second carbonatation. The saccharate is employed in all sugar factories that have a special plant for extracting sugar from molasses by the separation method.‖

* Z., **13**, 92, 1863.
† Z., **12**, 255, 1862.
‡ S, I., **1**, 35, 1866.
§ D. Z. I., **10**, 924, 1885.
‖ These establishments are termed Sugarateries by the author. These processes are discussed in full under another caption.

The process of defecation to be selected depends upon circumstances entirely independent of the action of lime, as when the modes of defecation are rationally applied to the epuration of juice no special difference in the results has yet been discovered, and theoretically none should exist.

(1) *Milk Lime—Advantages of milk of lime.*—According to HERZFELD * milk of lime is slightly more epurating than quicklime, but the juices are not so readily carbonated and when filtered are rather darker in color. The laboratory investigations of BEAUDET apparently prove the contrary, and it remains to be demonstrated within what limits these results have a practical value.

The devices for defecation with milk of lime are arranged in the factory proper, where the residuum scums are exhausted and as the lime kiln is far off it is more profitable to pump the milk of lime than to bring the lumps of quicklime to the factory. However, the last mentioned condition does not always obtain as the lime mixer may be placed near the kiln and the diffusion juice pumped into the carbonatation tanks.

As a general rule it is not desirable to pump limed juices for the wear and tear on the pump is excessive. In France and Belgium milk of lime is much liked on account of the regularity of its action and the facility with which it may be used.

(2 and 3) *Quicklime* (lumps and powder).—In favor of defecating with dry lime it may be mentioned that the action is more rapid and energetic than the defecation with milk of lime, so that in the first place one obtains the same epuration with a smaller quantity of lime, and, furthermore, the juice defecated with quicklime always contains a greater proportion of dissolved lime than that treated with milk of lime, consequently the operation of carbonatation is effected in a much shorter time and with a more complete utilization of carbonic acid. It is very doubtful if a thorough exhaustion of the defecation scums is advantageous, but as the resulting sweet water from an average washing is not sufficient for slaking the lime, one is obliged to use additional water as it is found undesirable to use for this purpose weak epurated juices. All facts considered, the fuel consumption is greater in beet-sugar factories defecating with milk of lime than where quicklime is used as the epurating element. The beet juices are heated several degrees by the slaking of the lime, while on the other hand, the sweet waters

* Z., 44, 291, 1894.

from the filter presses cool when brought in contact with lime during the milk-of-lime preparation.

The defecation should be accomplished with dry lime if only a limited volume of sweet water is obtained from the filter presses, and the lime kiln is in close proximity to the liming receptacle, so that the quicklime may be mixed without trouble and without any special installation for its transportation. As a general thing reference may be given to the quicklime method unless particular circumstances exist. It must not be overlooked that in several experiments it was found that in defecation with dry lime there were greater sugar losses and lower purity than when the milk of lime was used. However, in this connection many mistakes appear to have been made, as by reason of a poor application of the dry-lime method there was formed a soluble saccharate of lime which was not decomposed during carbonatation. For a like reason the statement that the quicklime epuration gives a gray sugar is not justified, as the grayish hue, when it appears, is due to other causes.

According to HERZFELD,* a more or less variable quantity of soluble saccharate of lime is formed during the defecation of beet juices, the amount being considerable when using dry lime. The carbonic acid acts on the soluble lime and this fact explains why the juices limed with dry lime may be more readily carbonated than those epurated with milk of lime. PELLET † very correctly points out that the quantity of lime dissolved depends upon the sugar percentage of the juice being treated, its temperature, the proportionate amount of lime added per sugar percentage and the period it remains in contact with the saccharine solution.

At the ordinary temperature, in weak juices and after long contact, there will be dissolved about as much lime as the proportion between it and the sugar required to form a monosugarate of lime. But as the temperature rises the solubility of the lime diminishes, so that at the ordinary temperature (80°) of liming there will be dissolved only 0.25 to 0.35 parts of lime in 100 parts of juice containing 10 to 12 per cent of sugar.

Insoluble saccharate (sugarate?) of lime may form as readily during the defecation with dry lime as with milk of lime, as the insoluble calcic salts that form during defecation have the property of carrying with them soluble calcic salts, and consequently a

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* Z., 44, 291, 1894. † Bull. Ass., 18, 885, 1901.

small quantity of saccharate. Insoluble precipitated saccharate is found in all defecated juices, when these are highly heated after defecation; in the epuration with dry lime, more lime will be dissolved, hence there will be precipitated more saccharate than in the milk-of-lime defecation. It is necessary to watch these changes closely, especially if the juices have been defecated with dry lime.

According to WEISBERG,* lime in a powdered or pulverized condition will give a greater loss of sugar in the form of saccharate, which remains in the carbonatation scums. By properly working, however, one of the conditions being that the temperature of the saccharine juices treated is sufficiently high, these insoluble sugar losses may be considerably diminished, and the filter scums need contain but a very low percentage. At one time it was claimed that caramel was formed by the use of quicklime, but BITTMANN'S † investigations on this point showed that the statement was erroneous and that there was not the slightest discoloration of the juice. It is to be noted, however, that in defecating with quicklime some important precautionary measures must be taken, such as keeping up a constant agitation and thus diminishing the ever-present danger of caramel formation. HERZFELD ‡ points out that the possible temperature during lime slacking may reach 468° C. There is ample authority to show that the use of quicklime during defecation produces harder scums than are possible with milk of lime.

Opinions appear to differ very much respecting the action of dry lime upon saccharine juices, as to whether it forms more insoluble saccharate of lime than the milk-of-lime method. The gray coloration of sugars obtained by the lime method is not due to an incomplete defecation, but to an incomplete carbonatation, in which the iron salts have not been precipitated. Consequently, if this operation be carefully supervised the sugars obtained will be of an ideal purity.

(4) *Powdered slaked lime.*—The experiments of HERZFELD § show that powdered hydrated lime gives the same results as milk of lime, but its use is considered not only unnecessary but also disadvantageous, owing to the cost and the work of bolting. Although the use of powdered hydrated lime has spread so little,

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* S. I., 52, 84, 1898.

† D. Z. I., 3, 1101, 1878.

‡ Z., 47, 830, 1897.

§ Z., 44, 289, 1894.

it is to be noted that it renders excellent services if applied during the second carbonatation, especially in cases where the liming is done with a saccharate. In factories where the lime is used in lumps, powdered lime is also added during the second carbonatation, and this is certainly an excellent practice, although it necessitates powdering slaked lime.

(5) *Saccharate of lime.*—The use of lime in the form of a saccharate was suggested by STAMMER.* It can claim no special advantage as compared with other modes. It is only used in the sugarateries.

**Quantity of lime.**—The quantity of lime thought necessary in various factories oscillates between wide limits. To neutralize raw-beet juices and precipitate the substances that may be precipitated by lime 0.15 to 0.20 per cent of lime is sufficient. A real defecation, one in which the scums are readily deposited and a clear juice floats on the surface, is obtained by adding 0.5 to 0.75 per cent of lime.

PELLET † has demonstrated that if only the minimum quantity called for by theory be added the epurating effects expected are not obtained, and hence the desirability of going to the other extreme. With such a small quantity of lime it would be difficult to work on a large scale, for the reason that the resulting scums would filter too slowly. One obtains an easy filtering scum after the end of saturation by using 1.5 to 2 per cent of lime. However, in many factories where this quantity of lime is accepted as a minimum it is not considered sufficient, and from 2½ to 3 per cent and sometimes more are added to raw-beet juices. It was thought that with larger amounts of lime the epuration of the juices would be greater. It is in effect true that by using more lime the juice will be clearer and will contain a fraction less calcic salt, but up to the present time there has not been noticed a perceptible difference in purity in relation to the amount of lime used.

Over twenty years ago von WATCHTEL ‡ pointed out that the quantity of lime to be used during defecation depended upon the amount of foreign substances the juice contained, and that a considerable excess of lime, to be subsequently rapidly eliminated through carbonatation, should bring about a mechanical epuration owing to the surface attraction of the voluminous precipitate.

SUCHOMEL'S § experiments, showing the influence of the quan-

* Z., **12**, 431, 1862.

† S. I., **17**, 146, 1881.

‡ Oe.-U. Z., **9**, 285, 1880.

§ *Ibid.*, **17**, 169, 1888.

tity of lime used during defecation, established the purity coefficient upon five combinations shown in the following table:

| Per Cent of Lime. | Purity. |
|---|---|
| 0.6 | 89.04 |
| 1.2 | 89.39 |
| 2.0 | 89.61 |
| 2.8 | 90.22 |
| 3.5 | 90.73 |

Juices defecated with 0.6 per cent of lime contained 0.336 of calcic salts expressed in oxide of calcium, and those that were defecated with 3.5 per cent contained only 0.008 per cent. This apparently demonstrates that when lime is in excess it precipitates the acids which would otherwise hold the lime in solution. On the other hand, HERZFELD'S * experiments concur in the fact that an excess of lime results in fewer lime salts in the solution. He noticed that the addition of 1.5 per cent of lime is not sufficient to obtain a satisfactory defecation, and that when lime is in excess the coloration is decidedly better, the purity of the juice higher, and the saline percentage considerably lowered.

CLAASSEN points out that the substances decomposable by lime cannot be decomposed more or less quickly by an increased amount, for in this case the lime dissolved may act alone and its quantity depend solely upon the sugar percentage of the juice and its temperature and in no way upon the quantity added. For this reason the more or less favorable action of increased quantities of lime is never shown during defecation but only when the juices are being saturated. Each case should be examined to determine whether the advantages are sufficient to counterbalance the numerous disadvantages resulting from the excessive use of lime, which not only increases the cost of the lime and carbonic acid, but also the volume of scum produced and the loss of sugar in the residuum; furthermore, it necessitates the use of a greater number of filter presses and a larger lime kiln.

**Excess of lime.**—There can be no doubt that an excess of lime very considerably retards the carbonatation, hence the importance of keeping the percentage within rational limits which will ensure both a satisfactory epuration and a rapid filtration of the resulting carbonated juices. If it is desired to obtain very clear juices, as

* Z., 44, 285, 1894; Z., 44; 287, 1894.

in the factories making special white sugar, the use of considerable lime appears justifiable, but it is never so in factories which manufacture ordinary raw sugar. Among those who have used unusually large excesses of lime HODEK,* who recommends 3 to 4.5 per cent, may be mentioned.

**Moderate liming.**—On the other hand, numerous efforts have been made to reduce the quantity of lime used to reasonable proportions. The early efforts in this direction were made by PERRIER and POSSOZ, and the most recent efforts bear a striking resemblance to those of the original promotors. The KUTHE and ANDERS † process originally involved the reduction of the amount of lime used during defecation. To diffusion juices, 1 to 1.25 per cent of lime, as milk of lime, and then granulated carbonate of lime were added, after which the mixture was filtered. The filtrate was submitted to a carbonatation, and the resulting precipitate was the carbonate of lime, subsequently returned in one of the phases of epuration. RAGOT ‡ has also given the question of lime reduction some attention. He treated cold juices with 0.2 to 0.25 per cent of lime, attaching no importance to the form in which it was used; to this was added 2 to 3 per cent of infusorial earth and to the filtrate 1 to 1.5 per cent more lime; this was followed by carbonatation. The infusorial earth could be entirely regenerated through carbonization. This mode, like many others, has made very little progress toward general adoption in the sugar factories of Continental Europe. These numerous combinations all possess one common characteristic which is the difficulty of the ultimate filtration.

**Gradual liming.**—That lime be gradually added was recommended by Possoz,§ by whom it was pointed out that the main advantage would be a more complete precipitation of the foreign substances and a reduction in the surface frothing.

**Conclusions and practical conditions respecting liming.**—After carbonatation the lime is necessarily removed in the form of a carbonate, which facilitates the filtration of the epurated juices. Upon general principles, it may be admitted that the greater the excess of lime carbonate the less will be the difficulty of filtration.

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* B. Z., **1**, 229, 1872.
† D. Z. I., **15**, 83, 1890.
‡ J. d. f. d. s., **49**, No. 38, 1897.
§ Possoz. Guide, Paris, 1873, p. 21.

It is to be noted that as juices contain widely varying percentages of foreign substances the excess of carbonate must necessarily vary with each special case considered. The defecating man by simple, practical observations can ascertain whether or not the liming is up to the desired standard. If it is the filtrate from the filter presses has an easy flow, and carbonatation continues during a normal period, and, furthermore, the general aspect of the limed juice to an experienced person gives all the necessary indications; for example, if the liming is sufficient the color is a cream yellow, when it is defective the hue is a gray black, while with the lime in excess the appearance is decidedly chalky. Also, when juices have been properly limed the lime they contain will rapidly deposit at the bottom of a test-tube and the surface liquor will be slightly cloudy and have a slight yellow color. The overseer of the factory should insist upon frequent tests being made of the limed juices, and modify the percentage of lime used to suit the requirements of each special case. Evidently, in theory, as the quality of beets being sliced varies every few hours, the percentage of lime used for defecation should also fluctuate, but this would be impossible in practice.

**Temperature of defecation.**—The most favorable temperature for defecation for normal beets is from 75° to 85° C. The lime should be brought into contact with the foreign substances in the beet juice at a high temperature, and the time of defecation be sufficiently prolonged to transform the nitric substances into ammonia, and as BODENBENDER * very correctly points out, this is one of the essentials for the elimination of calcic salts.

Upon general principles a temperature above 90° C., or boiling-point, cannot be recommended for defecation. However, when working very inferior beets, containing considerable invert sugar and other substances decomposable by lime, one may hope for a favorable action through high temperatures, but even then it is desirable to avoid boiling the defecated juices for any length of time, and it is better still not to boil them at all. The opinion that boiled defecated juices after their saturation give scums that may be readily filtered is not tenable.

Some experts claim that there are decided advantages under certain circumstances in heating at a very high temperature, but it remains to be proven within what limits the method should be

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* C., **30**, 712, 1880.

generally adopted. Boiling juices are not so readily saturated, and more sugar remains in the scums for the reason that in very hot juices there is less lime dissolved which can combine with the carbonic acid, and, furthermore, the very hot juices readily froth and render impossible the full opening of the entrance valve for the carbonic acid.

**Cold defecation.**—Cold defecation has been recommended, and in some cases adopted, on the theory that lime decomposes and redissolves a portion of the precipitated substances at a high temperature. This method of working was suggested by MAUMENÉ.* According to HERZFELD † cold defecation effects a more thorough epuration than hot, taking into consideration the elimination of saline and organic substances with a reduced coloration of the juice; but it must not be overlooked that such juices are not readily filtered.

On the other hand, CLAASSEN says that many experiments have proven that there is no appreciable difference between cold and hot defecated beet juices provided the cold defecated juices are reheated after the filtration as long as the calcic action remains between the usual practical limits. Cold defecation cannot be practically realized, as the scums obtained by this method do not filter fast enough even when combined with kieselguhr.

The AULARD ‡ method of cold defecation consists in bringing the beet juices into contact with lime at 20° C. for one hour, after which and before carbonatation they are gradually heated up to 70° C.

**Duration of defecation.**—The duration of defecation should be confined between determined limits. At low temperatures of 70° to 80° C. fifteen minutes is sufficient; at higher temperatures the operation should not last longer than five to ten minutes. BODENBENDER makes the assertion that the longer the period of defecation the better will be the results. In many beet-sugar factories lime is allowed to remain in contact with the juice for fifteen to thirty minutes before the carbonic acid is introduced, and AULARD extends the period of liming to two hours.

**Mechanical modes for the preparation of milk of lime.**—In beet-sugar factories working a comparatively limited number of tons of beets per diem the milk of lime is obtained by slaking in open

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* MAUMENÉ, Traité, 2, p. 226, 1878.
† Z., 44, 296, 1894.
‡ 5th Congress, p. 56, 1903.

receptacles. The best results appear to be obtained by using horizontal cylinders very like those used for washing boneblack in which the lime is perfectly slaked and with less danger to the workman. For the liming of beet juices preference appears to be given in Belgium and Holland to what is known as moist lime. The LACOUTURE appliance (Fig. 174) consists of a large cylindrical reservoir in which is a vertical shaft *b*, receiving its motion from *m*, and holding two arms *a* that are about 30 cm. from the bottom. To these arms are attached agitators, *p*, *d*, of varied shapes, which have a free motion and thoroughly mix the lime that falls to the bottom. The water used is sprayed over the lime through the perforated pipe *f*; *i* is a filtering surface which retains such lumps

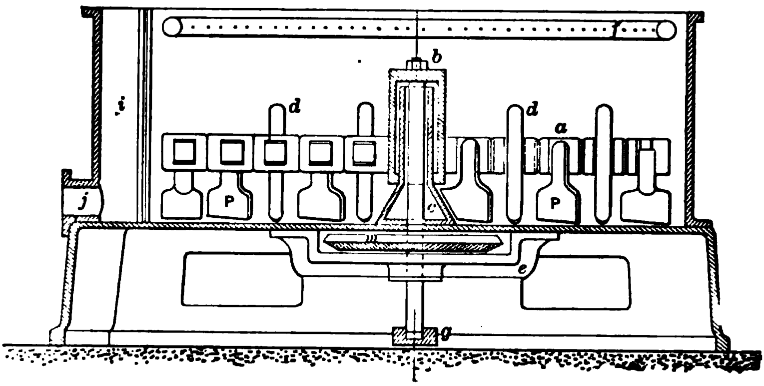


FIG. 174.—LACOUTURE Milk-of-lime Preparer.

as may not be thoroughly pulverized. The exit of the milk of lime is through *j*. The precaution must be taken to first slake the lime, for which purpose 20 kilos per hectoliter capacity are first introduced and a small quantity of water sufficient for the slaking. Then follows an elevation of temperature and the product falls in a pulverulent mass. This slaking demands time, as the lime always contains certain impurities, such as alumina, etc., which offer a certain resistance to immediate action.

In some factories the hot sweet water from the filter presses is used for the slaking, whereby the time necessary for this preliminary preparation of the milk of lime is shortened, but as there is a considerable rise of temperature during the slaking the sugar contained in the sweet water is necessarily destroyed. As soon as the slaking is complete considerable water is added and the agitator is set in motion. It is proposed that in order to increase the volume

of sweet water from the filter presses to be used in slaking, the washing of the filter press scums be pushed further and the resulting water be employed for the purpose, with the idea of producing the milk of lime at 20° Bé. MALANDER says that this corresponds to from 120 to 150 per cent of the weight of the scums.

In factories where the volume of the water in question is not sufficient diffusion juices are added to obtain milk of lime of the desired density. It is pointed out that the milk of lime should not have a density greater than 20° Bé., as it would then tend to clog the pipes, valves, etc., through which it circulates.

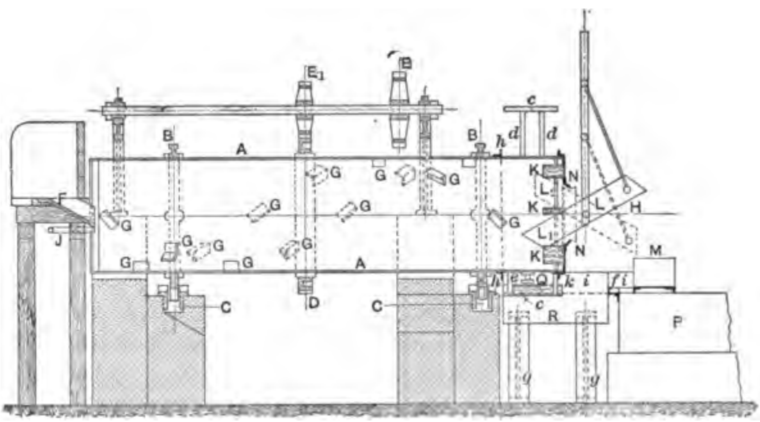

FIG. 175.—MIK Milk-of-lime Preparer.

The MIK appliance (Fig. 175) presents certain advantages. It consists of a long drum $A$ revolving on rollers and receiving its motion from the gearing $E$, $E'$. The lime passes into the drum through the hopper $F$, and the water is introduced through the pipe $J$, water and lime circulating together. The lime is constantly raised by the varied projecting surfaces $G$, arranged in different positions on the inner surface of the revolving cylinder, and after a certain time falls back by gravity into the circulating water—not at the same spot from which it was taken, but further along, thus helping the forward motion. It leaves the apparatus through the central opening $NN$ and falls into a reservoir $R$. The lime that has not been slaked is held back by the receptacles $K$, and when raised to a certain height falls into $L$ and then into $M$. This arrangement may be placed in the position $L_1$ or $L_2$, according to the purpose in view. In the position $L_1$ the non-slaked lime raised by $K$ falls back into the cylinder $A$. This apparatus

is used in many Austrian beet-sugar factories and renders excellent service in the production of a lime paste containing 30 to 35 per cent of oxide of calcium. Lime in this condition is sometimes used for defecation, but it is difficult to understand how it can be handled, and there is ample authority to show that the practice

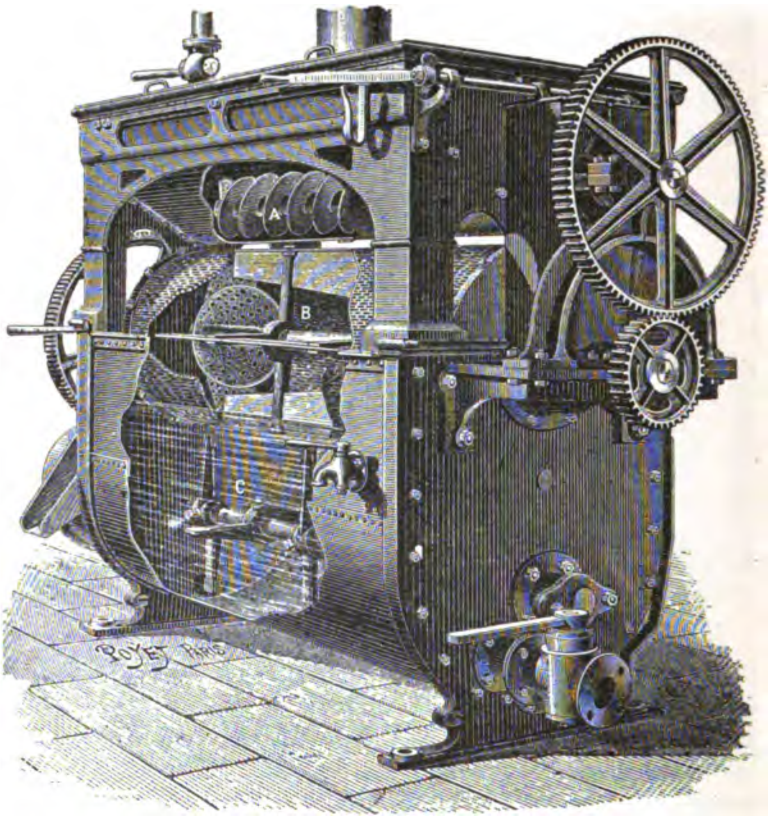


FIG. 176.—WACKERNIE Automatic Lime Preparer—"Hydrator."

is a great mistake. It has been suggested to use a paste of lime containing 20 per cent of water. The objection to this is that as the percentage of lime is uncertain one never knows the exact quantity which is being mixed with the juices.

Among the other interesting mechanical combinations for the preparation of milk of lime may be mentioned the WACKERNIE *

* S. B., 7, 1, 1886.

(Fig. 176) automatic apparatus, which saves considerable labor and may be said to be very economical. It does away with all lime dust which escapes through the chimney connected with the appliance. *A* represents the so-called hydrator. When the lime is slaked therein it falls into a lower cylinder *B*, which separates impurities, such as gravel, pieces of coke, stones, etc., and these when they have accumulated may be removed. The lime submerged in the water tank beneath is thoroughly mixed and the result is a milk of lime at the density needed at the factory.

To eliminate the soluble impurities existing in lime it has been proposed to slake the lime with considerable water, allow the milk of lime to deposit, and decant the floating liquid containing certain impurities in solution. This method has been practically carried out, but the greater portion of the lime contains only a small amount of salts soluble in water, such as the alkaline salts. The constituents of lime which dissolve slowly or rapidly, as, for example, silicate of lime and alumina, cannot always be eliminated by washing, because they are more soluble in saccharine juices than in water. Consequently there can be no advantage in this mode of working, and, furthermore, the operation is rendered more complicated and the properties possessed by milk of lime freshly prepared are not utilized. The older the milk of lime the less is its action on beet juices, for the reason that under these circumstances it combines with a large quantity of water; in other words, lime that has been slaked for a long time and left standing will defecate beet juices slowly and imperfectly. The milk of lime upon leaving the LACOUTURE apparatus passes through a suitable sieve, as before mentioned, but experience shows that there are important advantages in having it again strained so as to separate the still finer particles that may be held in suspension.

**Milk of lime filtering or straining.**—To separate particles of sand, etc., that may be mixed with milk of lime, von EHRENSTEIN * passes the solution through special grindstones, thus preventing the clogging of the appliances by foreign substances.

A special filter (Fig. 177) has lately been introduced into beet-sugar factories, its object being to separate all ash, sand, etc., that may be held in suspension. During this filtration lumps of lime which were not completely dissolved become liquid. The apparatus consists of two cylindrical chambers, one over the other. The milk

* D. Z. I., 10, 924, 1885.

of lime first enters the upper compartment and passes through a central strainer *A* before reaching the bottom. In the second compartment is a turbine *C*, the rotation of which forces the milk of lime through a cylindrical strainer *B*. In the extreme lower portion of the apparatus, which is conical in shape, the deposits are collected and may then be removed by the withdrawal of a closing valve or plug *D*, worked by the arm of a lever.*

After the preparation of the milk of lime it is drawn off by a force pump with common ball valves and sent to the defecation section of the factory, where its volume should be carefully measured before it is used. The pipes through which the milk of lime circulates should have ordinary valves so that the pump may be isolated should the occasion demand. These pumps are slow in action. Their velocity is 40 revolutions per minute, which, however, may be increased in an emergency, as, for instance, in case the slicing capacity of the sugar plant has been augmented, without a change in all the apparatus and appliances. The force pipe is run near the milk-of-lime measurer and then returned to the suction portion of the pump. When the communication with the measurer is closed the milk-of-lime supply returns to the suction pipe. There is comparatively little clogging in these pipes owing to the activity of the circulation.

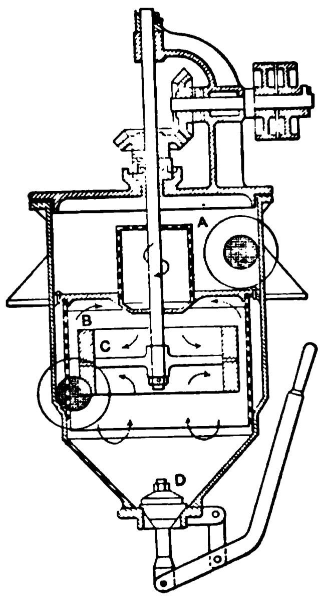

FIG. 177.—MUELLER Milk-of-lime Filter.

**Defecators.**—As a general thing the defecators consist of a receptacle in which there is a pipe for the entrance of the juice and an overflow for its exit. At the bottom there is a manhole for the removal of gravel, etc., that may be deposited during the operation of liming, and on the top is a chimney through which the vapors resulting from the slaking may escape. A special pipe at the bottom permits a complete emptying when the defecators need clean-

* C., 9, 667, 1901.

ing. When the defecators are to be emptied it can be done by putting this emptying pipe in communication with the overflow, so that the last portions of juice find their way into the carbonatation tanks. In Sweden this custom is very much in vogue. It does away with considerable labor and is economical in the long run.

The ROEHRIG and KOENIG * (Fig. 178) quicklime defecator con-

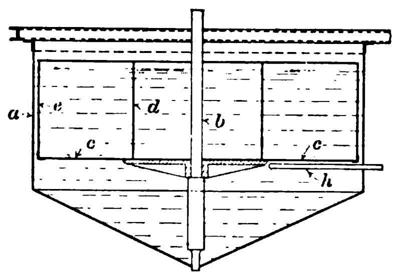


FIG. 178.—ROEHRIG and KOENIG Defecator.

sists of an annular iron basket *e*, the sides and bottom of which are perforated. This basket is attached to a vertical axis *b*, which forces it to revolve in the juice that is to be limed. With a view to obtaining an equal distribution of lime in the ring or drum a slanting

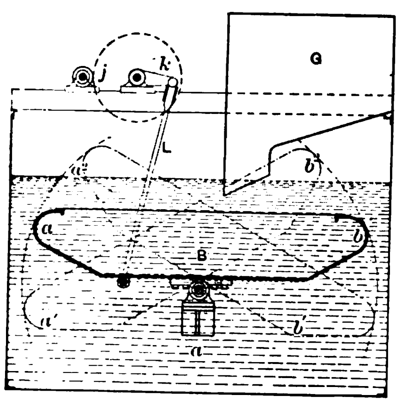


FIG. 179.—SCHEVER Defecator.

scraper is used, so arranged that it will not clog the perforations. In case of obstructions steam is forced through *h* and through the bottom *c*. The SCHEVER defecator (Fig. 179) is another device.

* D. Z. I., 25, 33, 1900.

It consists of a closed receptacle *a*, in which the perforated iron basket *B*, swings on a pivot. The lumps of lime are introduced into this through the hopper *G*. The swinging motion of the basket is obtained through the gearing *J* and the lever *L*. Very little lime is needed for the liming of the juice in *a*. The DUFAY defecator (Fig. 180), which is much used in France, works on very much the same principle as the appliance just described; but a horizontal, alternating motion is given to the basket *B* containing the lime through the gearing *G* and the lever *L*.

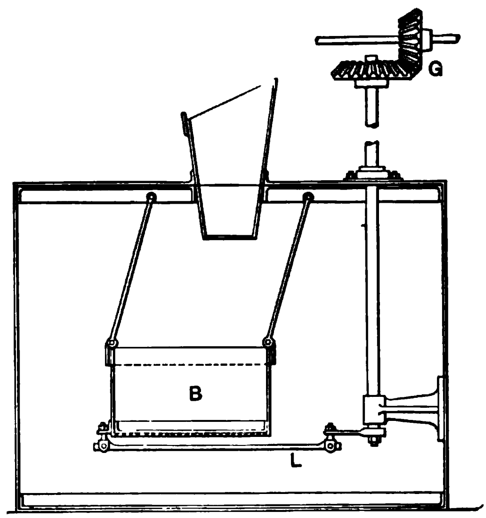


FIG. 180.—DUFAY Defecator.

**Measuring and weighing lime and milk of lime.**—As far as possible the lime should be used immediately upon leaving the kiln, for it then may be more readily slaked and will be quicker in its action. If the lime after standing crumbles, there is formed hydrated lime and calcic carbonate and its action is less energetic. It is very important to use the lime in lumps of moderate size, as its slaking is then more rapid.

There is nothing special to be said respecting the receptacle used for measuring milk of lime. In some factories it is customary to have in the interior of this measurer a scale which indicates the amount of the liquid to be used, the volume in question depending upon its density expressed in degrees Bé. Attention is called to the confusion which may follow if the density of the milk of lime has not been taken, for then too much or too little of the solution may

be used depending upon circumstances. In such operations there must be a thorough understanding between the overseer and the defecating man, and the necessary changes should be suggested by the chemist after a hasty laboratory examination. BUHRING* (Fig. 181) measures the milk of lime in a receptacle, *a*, having an upper scale attachment, *i*, which should be graduated in accordance with the capacity of the measurer. The scale has the divisions 2, 2¼, 2½, 2¾ and 3 per cent, corresponding to the percentage of calcium oxide. At the point indicating the percentage of lime to be used there is placed a pointer *k*. During the filling of the receptacle with the milk of lime a special spindle is used which will

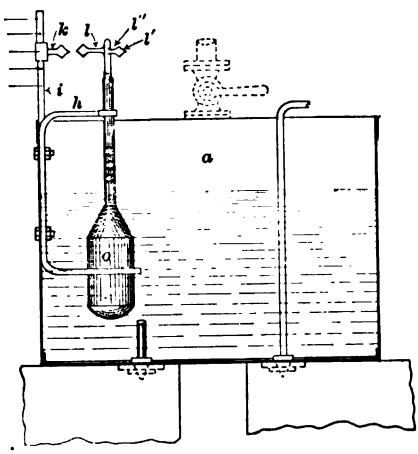


FIG. 181.—BUHRING Milk-of-lime Measurer.

sink or rise according to the density of the solution. The milk of lime is allowed to continue its flow into the measurer until the top of the spindle is even with the pointer. On this areometer is a graduated scale giving the density of the milk of lime, and three pointers *l*, *l'*, *l''* are placed at the same height so as to facilitate the observation when comparing with the pointer *k* of the upper scale.

The new apparatus of STOLC and CERNY (Fig. 182) is based upon the same principle as the measurer just mentioned. The float *O*, however, is better guided by the scale beam *N*. The pointer *p* should assume a perfectly vertical position when the desired amount of lime is introduced into *M* in the form of milk

* Z., 52, 62, 1902.

of lime. In that position the pointer *d* establishes an electrical communication and the defecator man stops the flow of the milk of lime into the measurer and opens *Q* to allow it to combine with the juice.

It would certainly be very desirable to have some means of automatically regulating the volume of milk of lime added to juices,

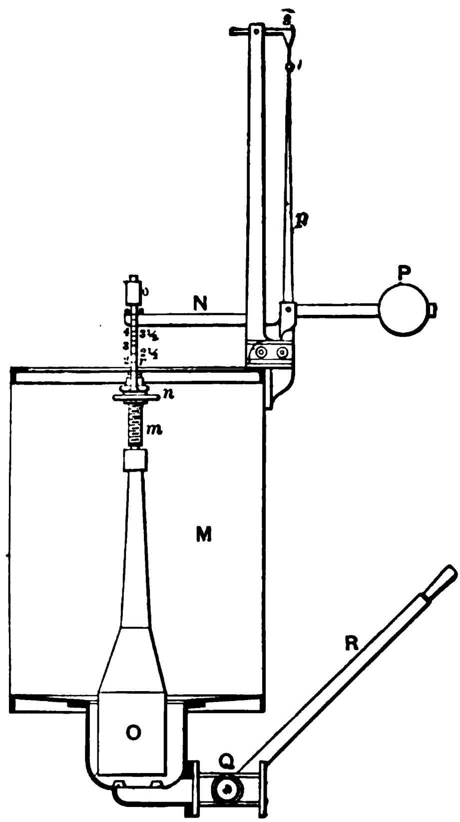


FIG. 182.—STOLC and CERNY Milk-of-lime Measurer.

but there are so many factors to be considered that it seems hardly practicable. For example, the ready filtration of a juice does not depend so much upon the percentage of lime added as upon the quality of the original beets. In most cases a small receptacle is used, its volume corresponding to that needed for defecating the juice from a diffusor. The emptying of one corresponds to the

emptying of the other. This mode of working is generally adopted when the liming is done with a saccharate.

When defecating with dry lime the lime is weighed or measured and the lumps should be as regular as possible. Although it seems more exact to weigh the lime it is preferable to measure it, for then the influence of the poorly calcinized and consequently heavier lumps have less influence. It is important to note that a hectoliter of lime in lumps weighs about 100 kilos. The defecation with dry lime and with quicklime may be continuously effected. The raw-beet juices enter from the bottom and pass by an overflow into the carbonatating tank. Each time the contents of the measurer pass through the lime mixer the requisite lime is again added.

**Juice and milk-of-lime mixers.**—By a method of carbonatation formerly used and sometimes employed even to-day, the operation of introducing carbonic acid into the juices commences as soon as the lime in the form of milk of lime has been added. A large part of the lime is then eliminated as a carbonate without having accomplished its purpose, and thus much more lime is used than when the liming and carbonatation are separate operations.

In factories where there is no mixing appliance the contents of the measurer are sent to the carbonatation tank. This mode of liming is objectionable as it does not give the lime sufficient time to act upon the juices. If the milk of lime is added in the carbonatation tank, as in the case just mentioned, the carbonic acid effects the mixing. After juices have been limed they are generally sent into a mixing tank whose volume corresponds to that of several diffusors. The arm agitators then bring the lime in contact with a considerable volume of juice and hasten the mixing. The desirable capacity of the mixing receptacle is limited by the fact that the entire operation should not last more than half an hour. However, AULARD is in favor of leaving the lime in contact with the juice for a much longer period and declares that the operation of liming and defecation should last at least two hours.*

**Lime and juice mixing.**—A lime mixer giving satisfaction is the KRACKHARD (Fig. 183) apparatus, which consists simply of a cylindrical receptacle in which revolves a vertical axis *a*, receiving its motion from an upper conical gearing *e* and *f*. This axis has a few small agitators *h*, and another horizontal axis *b*, which is

* 5th Congress.

made to revolve through *d*. The arm agitators attached to the horizontal axis bring about a violent agitation of the liquid, and the fixed rods *g* prevent a circular motion of the limed juice.

The lime and juice mixers vary greatly in shape. Those which are open on top permit one to follow the progress of the liming. Such mixers have a bottom opening for the entrance of the limed juice which passes out at the top through a suitable overflow. The overflow connects with the emptying pipe through which the liming tank can be completely emptied into the carbonatation tanks. This communication is closed during regular working. To heat the juice before carbonatation a steam coil

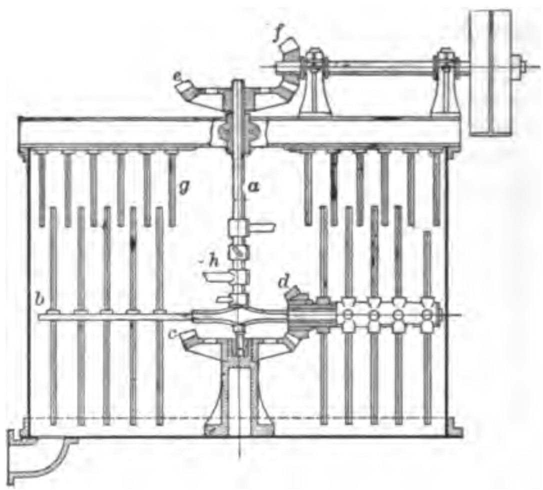


FIG. 183.—KRACKHARD Lime and Juice Mixer.

is frequently placed in the mixer, but as some sugar may thus be rendered insoluble this practice appears to be a mistake. The difficulty is abolished by heating the juices before liming. The limed juices leaves the mixers at about 90° C.

**Conclusions respecting defecation with quicklime.**—The defecation with quicklime at the present time is almost always effected by the addition of lumps of lime, about the size of one's fist, to diffusion juices reheated to 65° or 70°. This practice is very much in vogue in Germany, but in France and Belgium its first introduction met with considerable opposition. The arguments against its use were numerous, and manufacturers hesitated about making changes in their plants. The methods of using quicklime in powder

vary greatly. In most cases the slaking is done directly in the juice, but the objection to this mode is that there is danger of sugar inversion owing to the elevation of temperature, and for that reason preference is given to milk of lime, which requires preparation preliminary to its use.

When quicklime is brought in contact with beet juices it is slaked. Owing to the absorption of water the lime liberates considerable heat (1 kilo developing 150 calories on being slaked). The partial reheating of the juice brings about objectionable transformation and for this reason quicklime mixers should be constructed with considerable care, especially when lime is used which dissolves rapidly and energetically. It is absolutely necessary to throw aside the old mode of working, which consisted in introducing broken lumps of lime in an open wicker basket and submerging in the juices. In a rational method of working it is necessary to take into consideration the following facts:

*First.* Lime should be uniformly spread in horizontal layers so as to be brought in contact with the juice.

*Second.* The juice, and if possible the lime, should be continuously and sufficiently agitated.

*Third.* The easy and rapid emptying of stones and grits should be effected.

These considerations are observed in the lime-mixing receptacle by having the lime spread out on fixed or movable perforated plates, while the juice is put into motion by the rotation of a vertical axis on which are fixed arms above and below the sieve-like disks. The lime-mixing tank should have suitable manholes through which the stones and grits which have passed through the mesh of the sieve and also the semi-burned particles remaining on the disk may be removed.

## CHAPTER III.

### CARBONATATION.

As previously pointed out, limed beet juices contain an excess of lime in solution that must be eliminated, and to effect its precipitation the carbonic-acid gas from the lime kiln is used. After this operation, which is called carbonatation, the liquor is filtered to separate the precipitate, and the product obtained is called scums.

Formerly it was feared that carbonic acid when introduced into defecated juices would act as a solvent upon the precipitated substances. It was argued that to submit juices to the action of carbonic acid until they were neutralized, or even until they retained only a slight acid reaction, only blackened the scums. Consequently the substances precipitated by a preliminary defecation were eliminated by filtration, and only the clear juice was finally saturated. This method and its appliances have become obsolete.

At present juices containing an undissolved lime precipitate are generally subjected to carbonatation. From the defecating receptacles or reservoirs the juice is run into the carbonatation tanks. These are either round or square, open or closed, and are frequently of considerable height. In the lower part of the tanks are the apparatus for the gas distribution for carbonatation purposes, such as steam coils or live-steam injectors.

**Shape and size of carbonatation tanks.**—The bottom of the carbonatation tanks is sometimes flat, but there are many advantages in having it slant either on one side or better still towards the centre, which facilitates complete emptying. In modern factories one seldom, if ever, sees open carbonatation tanks, which have been found to possess many objectionable features, such as overflowing and throwing off an excess of carbonic acid, which was a source of discomfort if not of danger to the carbonatation man. The latter difficulty was in a measure overcome by the use of suitable draught

chimneys placed over the receptacle, but they worked only when the wind was in the right direction, when it was not the gas was forced back and for this defect there was no remedy. These wide chimneys still exist and are used for closed carbonatation tanks, carrying off the excess of gas that does combine with the lime during carbonatation. The capacity of the tanks varies very much, generally corresponding to the volume of two diffusors, and with proper manipulation there is needed at least four of these receptacles. In most cases in France three are used for the first carbonatation, while one is filling the other is emptying and the third is in full operation.

**Typical carbonatation tanks.**—In Germany preference is generally given to square or rectangular tanks. In the tank shown in Fig. 184 the bottom *B* has a slight slant towards the emptying valve

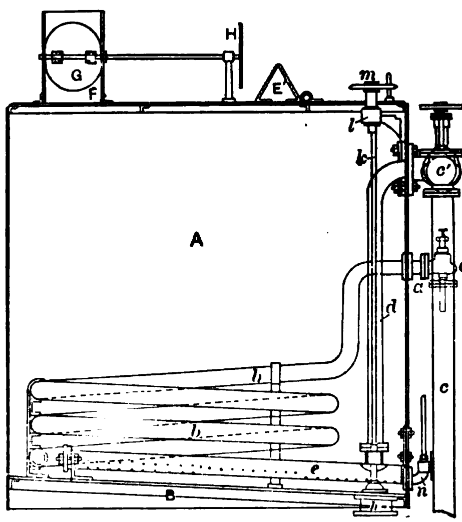


Fig. 184.—German Carbonatation Tank.

*h*. It is closed on top and the excess of uncondensed gas escapes through the chimney *F*. The escaping gas is regulated by *G*, the liquor being treated is heated by a steam coil *b*, and the carbonic acid is introduced through the pipe *c*, *d* into the bottom distributor *e*. In France* a carbonatation tank of very much the same design, but not nearly so high, has been used for many years.

* See Chapter on Filter Press.

In Fig. 185 is shown an Austrian carbonatation tank of the KARLIK type. It consists of a high vertical receptacle, on top of which is a chimney *G*; the bottom slants towards the emptying pipe *N*. The juice is introduced through *E* and is distributed by the disk *D*, from which it falls into *I*, which is the upper division of the carbonatator. The juice carries with it all the froth or scum

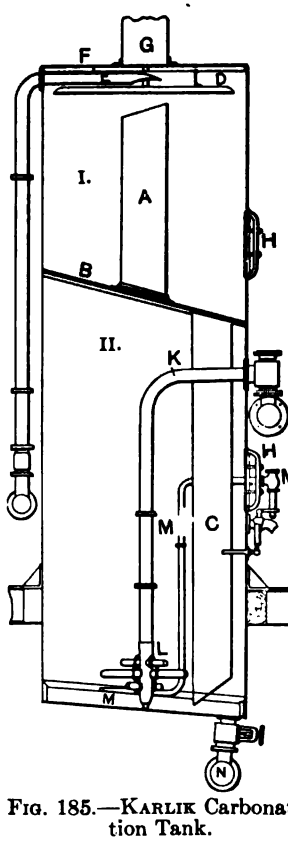


FIG. 185.—KARLIK Carbonatation Tank.

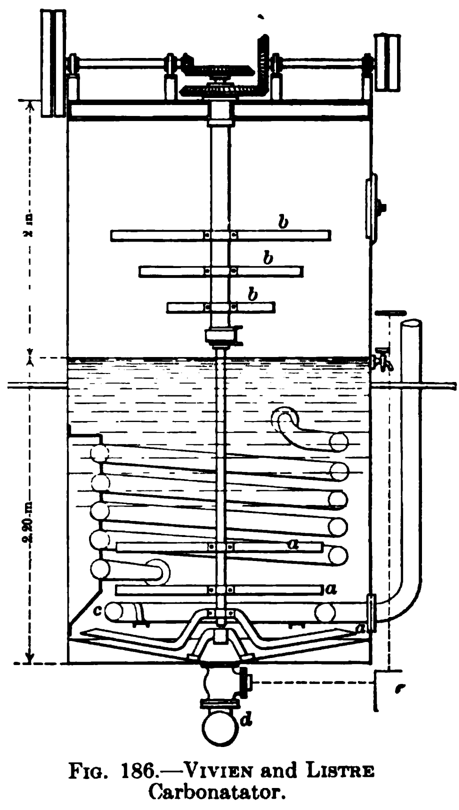


FIG. 186.—VIVIEN and LISTRE Carbonatator.

with which it comes in contact when passing through *C* into the lower section *II*, where the carbonatation is actually accomplished. The gas is distributed through *L* and live steam bubbles through *M* into the mass of liquor being treated. The resulting froth rises through *A*, falls onto *B*, and so the process continues.

The VIVIEN and LISTRE carbonatator (Fig. 186) is cylindrical in shape. It also has a steam coil and a carbonic acid gas distributor. The agitators *a* keep up the circulation, and the froth arrest-

ors *b* render excellent service; *d* is the emptying valve, while on the level of the juice is a small cock by means of which samples may be repeatedly taken during carbonatation.

The Mariolle Pinguet (Fig. 187) is one of the most recent types of carbonatators. It also is cylindrical in shape, but has no steam-coil attachments. The juice enters at *B* and leaves at *F*, the centrifugal froth arrestors being shown in *D*. The carbonic-acid gas is introduced at the bottom and is forced into the limed juice which runs down through *E*. Above the tank is the chimney *G* for the escaping gas.

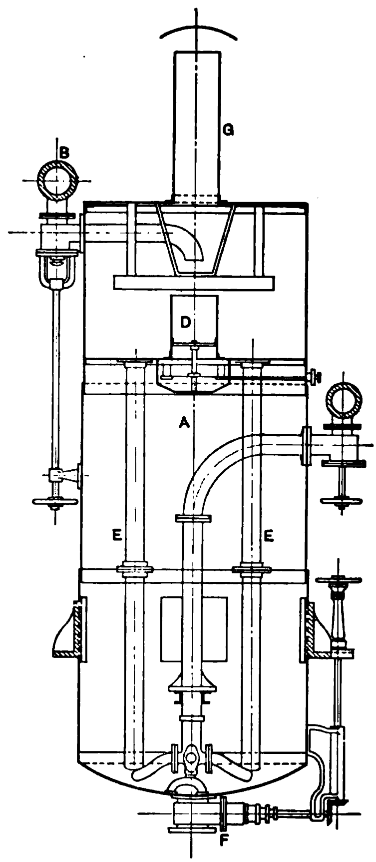


Fig. 187.—Mariolle-Pinguet Carbonatator.

The level of the juice in the carbonatators should be high enough to utilize thoroughly the carbonic acid, but it must not offer a counter pressure too great to be overcome by the acid pump. Keeping these points in mind experience seems to point to 2.5 meters as a satisfactory height. In the now obsolete carbonatating tanks very little space was allowed for the frothing, and numerous difficulties arose which could be overcome only by means of froth arrestors. In order that the froth or scum may have ample space it is very essential that the height of the carbonatators above the juice level should not be less than 3 meters. By allowing this ample space, frothing over is prevented and other devices for arresting the froth are rendered unnecessary. In Austria, where the colossal carbonatators frequently attain a height of 8 meters, froth arrestors have been dispensed with as a result of the practice of filling to only one-third of the capacity of the receptacle.

**Gas distributors.**—The carbonic-acid-gas distributors vary greatly in their arrangement and are generally placed at the bottom of the carbonatating tanks. The simplest form used consists of perforated pipes. CLAASSEN says that these are objectionable in that the gas passages become clogged, especially when they are small, and to clean or open them at the bottom of the carbonatation tank is not only difficult but dangerous for the workmen. There are combinations, especially in square tanks, which permit the tubes to be drawn out from the side, and one may thus remove such as are not working properly and replace them by new ones.

In the most satisfactory arrangement the gas-distributing pipe is bolted to the lower exterior sides with arm attachments, and by removing the nuts of the bolts and raising the flanges the pipes are readily taken out. The holes that are clogged may be readily opened by means of a triangular-pointed tool. The surface of

FIG. 188.—GUERERO Gas Distributor.

these holes should be of sufficient area, even when half closed, to allow all the carbonic gas that enters the distributing cock to circulate freely. The inside of the pipes also become clogged with lime deposits which may be removed by heating them to a red heat and then hammering. In the effort to obtain a satisfactory distribution of the gas these pipes have been made of varied shapes. Among these gas-bubble distributors may be mentioned the GUERERO * (Fig. 188) combination, consisting of a central pipe with radial perforated branches. While this arrangement gives satisfaction, it needs frequent cleaning. In order to do away entirely with the difficulties of cleaning, ROTHERMANN uses a gas-

* Z., 46, 261, 1896.

distributing box open at the bottom; the lower part is fringed and there are lateral holes for the escaping gas.

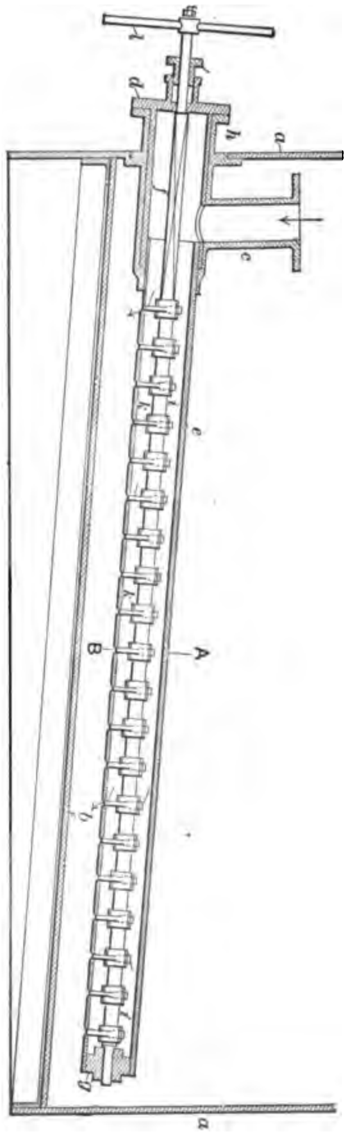

FIG. 189.—RICHTER Carbonic-acid-gas Distributor.

Another distributor of new design (Fig. 189) consists of a long slightly inclined pipe *e* placed at the bottom of the carbonata-

tion tank *a*. The carbonic-acid gas enters the pipe *c* and escapes through a series of openings at the lower part of the tube. The distributing is facilitated by a series of knives *k* attached to the axis *f*, which may be made to revolve by turning the arms *l*. Under these circumstances there can be no clogging of the passages with calcareous deposits, which would necessarily decrease the volume of gas coming in contact with the defecated juice during the operation of carbonatation.

FOGELBERG'S * arrangement for the distribution of carbonic acid in the carbonatation tanks consists of a pipe placed in the centre of the receptacle, the bottom of which is bell-shaped, and in it there is adjusted a cone which may be raised or lowered by a rod passing through the distributing pipe. The cone, if necessary, may be made to revolve so as to obtain a perfect joint, which is kept clean by the rotatory friction. With this arrangement it is no longer necessary for the workman in charge to enter the tank after it has been emptied of its contents.

WALLSTAL † says that satisfactory results have been obtained by perforations in the upper part of the carbonic acid distributing pipes in the carbonatators. Over the pipes in question are two iron plates placed in a slanting position and leaving an opening on top. The bubbles leaving this pipe are divided by the angle formed and rise on either side. It is claimed that under these conditions the carbonic acid is thoroughly utilized.

SCHNEIDER and HELMECKE ‡ arrange several cups at the bottom of the carbonatators connecting with a central pipe. These inverted cups have a number of openings which allow the carbonic acid gas an easy passage. They may be arranged in two series, an upper and a lower one, the lower row coming into use only when the upper is clogged and the passage of the gas is hindered.

In all the existing types of gas distributors the carbonic acid gas is utilized only to a comparatively small degree. The longer the road travelled by the gas in the juice the better is the absorption, and herein lies the explanation of the favorable action of thick layers of juice.

**Multiple utilization of carbonic-acid gas.**—KETTLER and ZENDER § (Fig. 190) proposed a multiple utilization of the gas from a lime kiln as shown in Fig. 190. The gas was introduced into

* Z., **51**, 65, 1901.
† Z., **51**, 965, 1901.
‡ D. Z. I., **24**, 756, 1899.
§ Sachs, Revue, **1**, 66, 1885.

one of the receptacles $A'$ for example; it bubbled up through the holes of the distributor $C$, then entered $T$, passed into $A_3$, then into $A_2$, and escaped through the chimney $H$, the valve $S$ of which alone remained open. If the gas was first introduced into $A_2$ it would pass into $A_1$, then through $T$ into $A_3$, and out through the chimney. Whatever the circulation only one chimney valve could remain open at a time. Owing to the complications necessi-

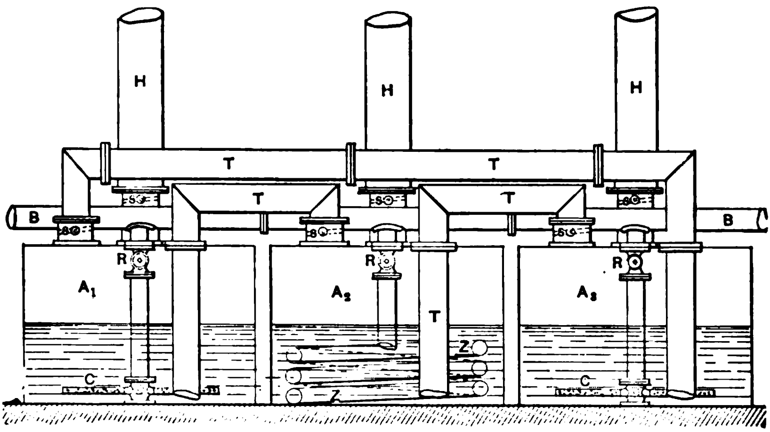


FIG. 190.—KETTLER and ZENDER Multiple Carbonatator.

tated in the manipulations of valves, and for numerous other reasons, the multiple gas utilization has been abandoned.

To utilize the carbonic acid gas drawn off in the chimney KNAUER* proposed to inject the juice as a spray, but this idea has not had any practical application for the reason that the pulverizators become clogged. Generally it is not necessary to resort to improved methods for carbonic acid gas utilization, as in all factories which burn their own lime there is always an excess of gas generated.

**Agitators.**—The practical utilization of the carbonic-acid gas increases as the gas bubbles rising to the surface of the juice decrease in size and as the mixture of the gas and the juice becomes more thorough. It is for this reason that turbines, gas injectors and also certain forms of agitators for keeping the juice in constant movement have given such satisfactory results. Such an agitating arrangement is shown in Fig. 186. An agitator of this kind should not

* Z., 32, 538, 1882.

have a velocity greater than 50 to 60 revolutions per minute. Some carbonatating tanks have baffle plates arranged along their inside surface to offer obstructions to the circulation created by the agitators. MALANDER points out that upon general principles the agitators are useless in such cases, as the gas circulating through the mass of liquid is alone sufficient to create all the agitation needed.

The MUELLER * plan of placing small turbines at the entrance orifice for the gas appears to offer some advantages as their action is to draw the gases to one side and the limed juice to the other. In this arrangement the carbonatating tanks are combined in such a way that the limed juice which has just come in contact with the gas, together with its froth, is projected into the other receptacle where the action of carbonatation is nearly completed. It is claimed that under these circumstances the existing alkalinity will cause the entire disappearance of the scums.

**Chimneys.**—As previously pointed out, both the open and the closed carbonatating tanks have upper chimneys to carry off the excess of gas collecting in a chamber that should be at a certain elevation above the carbonatating receptacle. The chimney itself is generally made of sheet iron and should extend at least 2 meters above the roof of the factory.

The gases and steam after their utilization escape through pipes of considerable diameter, so that if froth should be carried up by entrainment, it may be deposited. These pipes are generally given a diameter of about 30 cm. The chimneys have suitable coverings at the top to keep out the rain, etc. In case the frothing is excessive some of the froth frequently finds its way through entrainment to the top of the chimney, even in cases where it is 10 meters high. An excellent way to prevent the loss of these scums and the juice is to place a sort of funnel around the outside of the chimney where it leaves the roof. This funnel will collect the juice and froth and allow their return to the carbonatation tanks. They strike the upper cap and project downward upon the outside funnel and then flow back through vertical slits in the iron chimney. Sometimes these pipes have an enlarged portion serving as juice separators.

When each carbonatator has not its own escape pipe or chimney and when the gases from the several carbonatators collect in one

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* N. Z., **41**, 60, 1898.

pipe $C$ (Fig. 191), it is important to take some precautionary measures that the froth from one carbonatator may not find its way into another, because the non-carbonatated juices would be brought in contact with those in which the operation is complete, and this would render the filtration of the scums more difficult and would tend to clog the scum filters. The escaping gases all run into $D$, and the froth and juice find their way back to $A$ through the pipe $F$. In order to allow an examination of the composition of the escaping gases a cock is placed between the escape pipe and a gas reservoir, from which the sample may be taken.

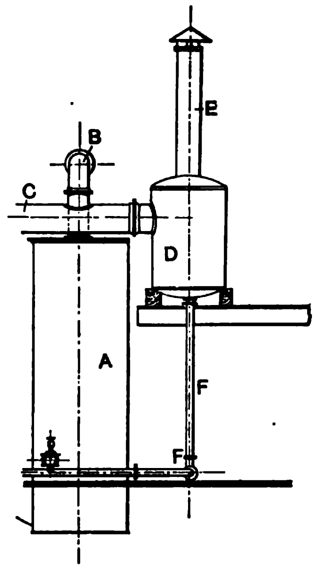

FIG. 191.—Juice and Froth Collectors.

In some factories the chimneys have valves as shown in Fig. 190. This permits a thorough regulation of the gases, with the object of realizing the most complete utilization possible; but this regulation offers an objectionable feature in that it retards the general operation of carbonatation. Do what one may there is always a considerable deposit left in the chimney which should, therefore, be thoroughly cleaned after each campaign.

**Froth arrestors.**—Froth arrestors have been shown in several of the typical carbonatators already described. They should revolve at considerable velocity, at least 120 to 150 revolutions per minute. The object of the arrestors is to break all the gas bubbles with which they come in contact, but their efficacy is not always as great as might be wished, and as they cannot be applied to square or rectangular carbonatating tanks for these other methods must be used. Among such devices may be mentioned the coil arrestor and the addition of some fatty substance to the surface of the liquid; but in addition to the important item of expense many kinds of grease or oil render the juices so much the less pure and are responsible for difficulties during the filtration in the scum presses. However, as the use of small quantities of oil or fat cannot be entirely obviated one should use a kind having a certain

viscosity, such as tallow, castor oil, etc.; and, although only a small quantity is employed, the amount should be constantly watched. One arrangement is to have an oil receptacle with an automatic level indicator placed at a certain elevation, the oil being pumped or forced out into the carbonatator. The pressure may be advantageously obtained by means of a communication with the carbonic-acid pump.

The use of grease as a froth arrestor is not to be recommended, not so much on account of the possibility of introducing foreign substances into the juice as on account of the subsequent difficulty in filtration, especially in the low-pressure filter presses through which the juices run before evaporation. The difficulties of filtration which result from the fatty substance added do not present themselves in the filter presses for first carbonatation juices. HERZOG declares that after the grease has been added to the surface of beet juices there follows a saponification in contact with lime. The lime oleates are soluble in saccharine solutions, and this solubility increases with the concentration. These oleates have very little influence on impure saccharine solutions. It is claimed that the solution of calcareous soaps in saccharine juices is due to the formation of a saccharate. However, in the presence of calcium oxide there follows a combination of the saccharate and the oleate of lime, forming an insoluble compound which is without influence upon the filtration. Consequently one need have no hesitation in using a fatty-froth arrestor when the need presents itself, although in the most recent methods very little use is made of this expedient. The nature of the fatty substance has an important influence on the results obtained. The gas bubbles of which the froth consists are more readily acted upon by a viscous grease than any other; hence there is a tendency to use mineral oils for the purpose, but the practice is not desirable, for they of all others become important obstructors in the filter press. Among the most desirable fatty substances to be used as froth arrestors may be mentioned castor oil, tallow, cocobutter, etc. It must not be forgotten that froths are frequently due to some faulty mode of working or to some inattention on the part of the carbonatation overseer.

Generally the use of steam is resorted to as a means of arresting the froth formed during carbonatation. This is objectionable as it involves a considerable loss of steam. In some beet-sugar factories exhaust-steam rather than live-steam is used for the

purpose, but this plan is economical only in case there is an excess of exhaust-steam available. The froth-arresting pipe has a diameter of 2.5 cm. and runs around the upper border of the carbonatating tank about one meter above the level of the juice in the receptacle. This pipe has numerous perforations, about 3 mm. in diameter, and terminates near the centre of the receptacle. Such froth arrestors need very little cleaning during the active compaign of a factory. The carbonatators shown in Figs. 185 and 187 have suitable separations *A* and *D* for collecting the froth, which after becoming more fluid readily flows to the bottom through the large pipes.

**Heating defecated and carbonatated juice.**—Closed coils do not seem to be suitable for reheating defecated juices as they soon become covered with incrustations and are then not economical. For reheating the juices in these receptacles it is better to use live-steam injectors. Experience seems to show that it is better not to reheat the defecated juices until the carbonatation is completed, and then a high temperature is always found desirable. To prevent the dilution of the juices which always follows the use of live-steam for heating, and also to utilize the less expensive vapors from the evaporating appliances, it is recommended to pump the carbonatated juices through tubular reheaters, through which steam circulates to at least 100° C. There need be very little apprehension as to lime deposits when the juices enter the heater at the top and flow out from the bottom.

The reheating of the juices in connection with the operation of carbonatation is not essential. According to HERZFELD * the operation continues after a certain temperature, say 60° C. has been reached, with about the same rapidity, whatever the degree at which it is conducted, provided the temperature be kept within reasonable limits.

**The valves.**—At the bottom of the carbonatation tanks there are two tubes, one for the entrance of the limed juice and the other for its exit after it has been submitted to the action of carbonic acid. For either open or closed carbonatators these pipes have suitable closing valves placed outside of the receptacles. This arrangement is better than the bottom valves as they cannot be clogged by the falling of deposits from the sides of the carbonatators where the joint connection is made.

* Z., 44, 393, 1894.

In the case of closed carbonatators these valves are manipulated by the turning of a top wheel *m* (Fig. 184) mounted on the end of the vertical rod *d* which leads to the bottom valve *h*. The seat of these valves occasionally becomes clogged, but the difficulty may be readily overcome.

**Juice sampling.**—On most carbonatation tanks a small cock is placed on the outside at the level which the juice should reach

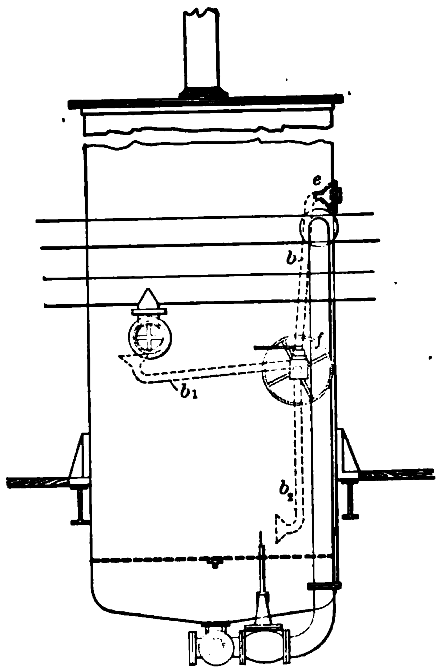


FIG. 192.—Juice Sampler.

in the interior of the receptacle. This permits one to ascertain whether the desired quantity of juice is in the tank, and also facilitates the taking of a sample when the necessity arises.

A carbonatated juice sampler* (Fig. 192) of a new design consists of a pipe which penetrates the carbonatator and can be made to revolve by a suitable appliance. On the exterior of the carbonatator is a well-arranged cock attached to the pipe and curved downward. When the sampler is made to revolve 180° the liquid it contains flows through the exterior cock. As the

* B. Z., 25, 493, 1901.

pipe *b* passes through different layers of liquid an average sample can be obtained.

**Changes during carbonatation.**—Many chemical changes take place during carbonatation which are not entirely understood. At first, because of the introduction of carbonic acid, there is no formation of calcic carbonate, but a complex combination of calcic carbonate, saccharate of lime and possibly quicklime, forms a gelatinous precipitate which contains a large quantity of sugar in the shape of insoluble calcic saccharate.

Barreswill and Dubrunfaut declared many years ago that the substance which made the carbonatated juices gelatinous was a double combination of a carbonate and saccharate of lime, and while certain French chemists call this combination a sucro-carbonate up to the present time chemists in general do not agree as to its composition. Weisberg and Loiseau * maintain that the three substances, sugar, free lime and calcic carbonate, in the presence of each other form one substance and thickens the juices; they call this combination a sucrate of hydrocarbonate of lime. On the other hand, Herzfeld declares that during carbonatation there is formed a carbonated calcic saccharate. At first a small quantity of tribasic saccharate is separated, which explains the decrease in the saccharine percentage determined by Weisberg; † this will, however, be followed by an increase if the carbonatation is continued. The tribasic saccharate and the carbonated calcic saccharate will assume a gelatinous condition, which explains the unsatisfactory working of the filter presses when the carbonic acid has been too sparingly used.

Claassen says that besides the immediate neutralization of lime carbonatation brings about other phenomena, some of which may be considered favorable while others are decidedly unfavorable. Among the beneficial effects one must consider the precipitation of soluble calcic salts at the same time as the calcium carbonate. This precipitation can only be attributable to the formation of double salts. The amount of calcic salts carried down depends upon the quantity of lime used during defecation.

Another consequence of the carbonatation is that the gelatinous or flaky organic or inorganic substances formed during defecation become heavier through contact with calcium carbonate. The lime precipitation is comparatively slow, but its formation

* Bull. Ass., 16, 179, 1898. † Ibid., 168, 1898.

may be hastened by furnishing certain nuclei, such as the small particles of scum floating in the juice. These would in their natural condition be difficult to handle during filtration, but as they become partly or entirely covered by calcic carbonate they necessarily lose their gelatinous consistence and offer no difficulty. Carbonatated juices are always more readily filtered than those that are limed, even when to the latter lime or infusorial earth is added, as the mixture does not take the place of the precipitation which carbonatation causes. A certain amount of sugar frequently remains in the scums as saccharate of lime, which brings about an unfavorable action despite the care taken in operation of carbonatation.

Herzfeld * has noticed this phenomenon, especially with milk of lime.

**Carbonatation scums.**—The amount of insoluble saccharate of lime that the scums contain may be attributed to three causes: (1) To the precipitation of saccharate of lime during defecation, due to overheating the juice, or to excessive heating after the lime has been added; (2) To the fact that a portion of the saccharate of lime at first precipitated as a double combination remains insoluble even after the end of the carbonatation; (3) To the fact that the calcic carbonate is precipitated at the same time as the insoluble calcic compounds which are formed during either defecation or carbonatation. The amount of saccharate of lime which becomes and remains insoluble is generally very small, but it is apparent under favorable circumstances when these three causes work simultaneously. The consequence of these calcic precipitations is that the scum deposits in the filter presses contain an increased amount of sugar, which is very difficult to reduce even after a continued washing, and causes a decrease in the purity, as the juice contains less sugar in proportion to the quantity of non-sugar present.

**Absorption of carbonic acid.**—The absorption of carbonic-acid gas during carbonatation is attended by several phenomena. At the beginning of the operation nearly all of the gas from the lime kiln is absorbed by the limed juice, as has been demonstrated by Boner.† Then the absorption gradually decreases as the liquor thickens and decreases in alcalinity, and again becomes more abundant as the sucro-carbonate decomposes. Towards the end of the

* Z., **44**, 283, 1894.

† Oe.-U. Z., **17**, 627, 1888.

carbonatation * the greater portion of the carbonic acid is again absorbed.

**Variation in alkalinity.**—The defecated juice is very alkaline, but varies very considerably with the limed juice being treated. The causes upon which this alkalinity depends remain unknown, no explanation offered by the leading authorities being entirely satisfactory. The form in which lime is used for defecation has an important influence, the alkalinity of the limed juice when milk of lime has been added being unlike that obtained by quicklime, for example. The initial alkalinity of the limed juice varies between 0.34 per cent and 0.9 per cent of calcium oxide. It is most difficult to determine just when the gelatinous precipitate is formed, but one fact is certain, viz., that the abundance of the precipitate varies in proportion to the original alkalinity existing before the carbonatation begins. During the first period, it is true, the alkalinity declines rapidly from 0.25 or 0.35 per cent to 0.15 or 0.18 per cent, but after that it remains almost stationary, because the juices dissolve as much lime as the gas precipitates. When all the lime is finally dissolved the alkalinity falls rapidly from 0.15 or 0.18 per cent to 0.7 or 0.10 per cent, and that is the condition in which filtration may be best effected. Consequently it is toward the end of the operation that the carbonatation overseer should devote his especial attention to the work in hand in order that the process may not be pushed to an extreme limit.

All the lime is not eliminated from the juice, as there remains in solution 0.07 to 0.15 per cent, depending upon the mode of working and the nature of the diffusion juice being handled.

Upon general principles it may be admitted that for a satisfactory filtration and epuration the lowest alkalinity corresponds to the purest juice. Some authorities claim that the alkalinity is apparently proportional to the non-sugar eliminated from the juices during defecation. By dilution of the liquid, either with water or with saccharine solutions containing no substances that will precipitate, the alkalinity of the juice may be lowered, effecting at the same time a like degree of epuration and facilitating the filtration. If the carbonatation continues the limed juice will change color and the filtration will become more difficult. However, for the same juice there are different alkalinities at which the filtration is very satisfactory. If the carbonatation is still

* Bull. Ass., **16**, 176, 1898.

further continued the subsequent filtration will offer no difficulty, but the filtrate will have a dark color and possess many objectionable features, which will be subsequently discussed.

There follows a precipitation of the organic acids of the alkaline and ammoniacal salts with the liberation of ammonia and the alkalies, the acids forming insoluble calcic combinations. Among these are phosphoric, oxalic, tartaric, citric, succinic, glycolic, glyoxalic acids, etc. Oxalic acid is the most important of the series, as it combines with 42 per cent of the alkalies of the juice.*

**Chemical control.**—No definite rule can be given for deciding when the carbonatation is finished, but certain empirical indications have an important practical value, as for instance, the froth loses its viscous appearance. As to the sampling of juice, it is well known that in experienced hands its appearance alone is a sufficient indication as to whether the operation has been properly conducted or not, but it may be subsequently filtered and its alkalinity determined. This estimation offers no difficulty and may be made upon a given volume of beet juice before filtration. A few drops of an alcoholic solution of phenolphthalein is added and reddens in the presence of alkalies. Then a titrated sulphuric acid solution is added until the red color disappears.

Titrated sulphuric acid, as generally used, is a very dilute acid, in which one cubic centimeter will exactly neutralize one milligram of quicklime. Consequently, 13 cc. of sulphuric acid used in the titration would correspond to 13 mg. of quicklime in 10 cc. of juice or 0.13 per cent, each cubic centimeter corresponding to 0.01 per cent, and the juice would be said to have an alkalinity of 0.130 per cent. The alkalinity is not due to lime alone. While the rosolic acid and the phenolphthalein tests do not give exactly the same results no importance need be attached to this fact, provided that either the one or the other be taken as a standard in the laboratory. Some chemists highly recommend the use of specially prepared test papers which retain their color until the standard alkalinity is reached. While during the first carbonatation the indications are misleading, for the second saturation they are most satisfactory.

**Oxalic acid.**—The alkalinity of the juices treated will differ in every factory. It is for the chemist of the sugar factory to determine exactly what degree of alkalinity the carbonatated

* B. Z., **23**, 596, 1899.

juices should have to give the best results. ANDRLIK and STANEK have found very variable quantities of oxalic acid in diffusion juices. It is possible to eliminate this acid only by maintaining during the last period of carbonatation a constant alkalinity of 0.1 per cent expressed in lime. If the alkalinity is too low there will be no relation between the quantity of oxalic acid in solution and the solubility of the calcic oxalate; the excess of this acid will have the great disadvantage of forming a deposit on the heating surfaces or receptacles with which it comes in contact, while the calcic oxalate will be carried forward during the various manufacturing operations, to be ultimately found in the residuum molasses, where its presence is very marked during the operation of osmosis.*

**Saccharate of lime.**—As before stated, a saccharate of lime is frequently precipitated in the juice, which will not be readily decomposed by carbonic acid gas, and this results in a loss of sugar in the scums. When a considerable amount of saccharate of lime is precipitated and the scums are not readily exhausted of their sugar, efforts should be made to overcome the difficulty by lowering the alkalinity as much as possible. As one may be certain that the insoluble saccharate of lime will decompose only in juices not containing free lime, it is recommended that the carbonatation be pushed to the extreme limit when scums are difficult to free of their sugar in the filter presses; that is to say, one should saturate not only the alkalinity due to free lime, but that also which is the outcome of alkalies.

The juices and scums under these circumstances assume a dark-colored hue and an unpleasant aspect. The scums no longer give satisfactory deposits and the floating liquor is cloudy. A juice of this sort conveys an excessive carbonatation and cannot be readily filtered. But if a small quantity of milk of lime or recently defecated juice be added, so that the alkalinity rises at least to 0.1 per cent, the mixture seems again to assume its former appearance and the properties of a saturated juice of the same alkalinity.

**Non-sugar.**—WOLF † and many of the leading chemists claim that there is always a certain percentage of non-sugar dissolved when the carbonatation is pushed beyond a given limit. On the other hand, SUCHOMEL ‡ has proven by actual experiments that

* B. Z., **24**, 52, 1899. † Oe.-U. Z., **21**, 288, 1892. ‡ Oe.-U. Z., **17**, 160, 1888.

it is a mistake to suppose that the purity of the juice will be lowered when the carbonatation is carried beyond the standard limit, and that, on the contrary, there will be a rise in purity until a point of absolute neutrality is reached. According to MENDES,* the most pronounced coloration reached is in reality the outcome of the formation of a ferric glucinate at the expense of the calcic glucinate. The first mentioned has a violet-blue color and the second is slightly yellow. These assertions have been corroborated by practical tests made by BODENBENDER.†

Excessive carbonatation, by continuing the action of carbonic acid upon solutions that are neutral or slightly acid, without doubt produces poorer juices. The non-sugar, calcic salts, and the coloring substances are redissolved. It has not yet been proved whether, by mixing juices which have been brought in contact with an excess of carbonic acid with milk of lime or defecated juices, all the non-sugar dissolved will again be precipitated. In all cases this would appear to be possible, for in practice no difference is noticeable between such juices and those directly carbonatated, when the carbonatation, although not pushed to an extreme limit, has been continued for a short time and when sufficient lime has been added for the mixture to have an alkalinity greater than 0.10 per cent.

The most objectionable feature of excessive carbonatation is the influence upon the magnesia salts which are introduced into the juice by the lime, as it has been proven that the carbonate and lactate (especially the latter) have considerable influence on the facility with which carbonatated beet juices will filter. Magnesia also takes an active part in the supersaturation of these juices; this chemical is then dissolved, but is precipitated in the scums of second carbonatation. This explains why juices of second carbonatation from supersaturated juices of first carbonic-acid treatment will not filter as well as juices which have been normally treated. Some careful laboratory investigations show that the scums of second carbonatation frequently contain lactates of lime and magnesia, but it has not yet been proved that these are normal or that they indicate a faulty method of working.‡

**Elimination of calcic salts.**—The lime salts formed during defecation are generally eliminated during first carbonatation, but in some respects it appears more advantageous to wait until

* J. d. f. de S., **14**, No. 51, 1874. † Z., **25**, 122, 1875. ‡ Z., **49**, 779, 1899.

the second carbonatation before entirely completing the operation. PELLET recommends that the calcic salts be precipitated before the second carbonatation, and this idea agrees with HERZFELD's theory; WEISBERG,* on the other hand, urges that it be done after the second saturation.

Since the early history of beet-sugar making, it has been noticed that calcic salts render graining in the pan most tedious. It has always been customary to depend upon soda for the elimination of these salts. Soda in the presence of calcic salts undergoes a double décomposition, the sodium attaching itself to the acid radical of the calcic salt while the calcium combines with the carbonic acid of the soda to form an insoluble calcic carbonate which is eliminated from the juices with the scums. Then these juices instead of containing calcic salts retain salts of sodium which, upon general principles, are far less objectionable. Too much stress, however, must not be placed upon this action, as it frequently happens that the expected purity is not realized and the juice always retains a certain percentage of lime which must be subsequently eliminated. To entirely accomplish this by means of a sodic salt would not be practically possible owing to the large quantity necessary. It is to be noted that in practice larger quantities of soda must be taken than theory would lead one to suppose. The juice itself contains numerous substances besides the one under consideration, and for their elimination an excess of the purifying agent must be used. Experience shows that this reaction offers exceptional difficulties in the case of concentrated juices, and for this reason the treatment of syrups by the sodic methods has been largely abandoned. PELLET † strongly urges that the calcic salts be precipitated in hot diluted juices which facilitates the reaction. It is within the province of the chemist to determine with an alcoholic-soap solution exactly what is the percentage of the lime salt in the solution, and to ascertain within what limits the soda treatment is practically realizable.

**The carbonatation of defecated juice** demands considerable attention. If it is badly done numerous perturbations may occur in the working of the filter presses. The responsibility of the carbonatation overseer is as great as that of the diffusion battery chief, especially when the juices are of poor quality. Where there is a special defecation station the overseer should personally

* S. I., **38**, 567, 1891.

† S. I., **38**, 573, 1891.

make sure that the juices have been well defecated before the carbonic acid is introduced. A sample should have a precipitate that will freely deposit in a clear floating liquor. The filtrate should show an alkalinity of from 0.25 to 0.35 per cent, depending upon the temperature of the juice, when quicklime is used in defecation and somewhat less if milk of lime is employed.

**Filling.**—It is customary to fill the carbonatation tanks always to the same level. Two objects should be constantly kept in view: The practical capacity of the receptacle should be utilized and at the same time sufficient space should be allowed for the surface frothing. If the levels were different in two tanks into which carbonic acid was simultaneously introduced numerous complications would follow. The gas could not overcome the resulting difference of pressure, and as it would move in the direction of the least resistance the operation in one tank would be finished sooner. When the carbonatation tanks are open this regular filling offers no difficulty, and for closed tanks floats with outside indicators are used. With this arrangement the difficulty is that the rod connected with the indicators penetrates the top of the carbonatation tank, which should be hermetically closed. A better method is to fill the tank until the juice runs from a lateral cock at a given height. Other practical modes have given satisfaction, for example, by floating a block of wood on the surface of the liquid its level may be observed through lateral peep holes. In order to ascertain whether the tank is empty steam is run into it through the carbonic-acid-gas distributing pipe. The sound made when it escapes at the exit orifice gives the necessary indications.

**Introduction of gas.**—When the carbonatation tank is filled up to the desired height the valve for the entrance of the gas is at first only partly opened, as the frothing is always greatest during the first few moments. That the pump may continue its work without variation and the gases be more thoroughly utilized, not only is the connecting valve of one tank opened but those of two or three, under which circumstances the tank which is most under the influence of the carbonic-acid gas and in which the frothing is least will receive the greatest amount of gas. The carbonatation tanks must each be made ready in turn, but at regular intervals. There are no advantages in having several ready at the same time, as the scum pump can take but one at a time.

**Sampling and indications.**—During the epuration frequent samples are taken to ascertain the condition of the deposited pre-

cipitate. If the tanks are open on top the sampling is done with a sort of long-handled spoon or with a small pump. With closed tanks, where the person in charge stands at the base of the receptacle, the sample is taken through a cock. Experts can conduct the operation with almost mathematical precision when the sampling in question is properly done. Some overseers take as a guide for the conduct of the carbonatation, the manner in which the gas bubbles burst upon passing through the juice. The appearance of the juice during the operation is a very important guide for its successful working.

As soon as the carbonic acid gas is introduced the liquid juices begin to thicken, and this increases in proportion to the sugar percentage and the degree of the concentration of the juice drawn from the diffusors. The sample in the spoon is gelatinous and does not show any deposit. The consequence of this gelatinous condition is extreme frothing at the commencement of the carbonatation and the excessive bursting of the gas bubbles that pass through the liquid being treated. To filter the juice at this stage is impossible, and should it through neglect get into the scum presses clogging will quickly result. During the period that follows the introduction of the carbonic acid gas the gelatinous consistency of the juice gradually diminishes. The gases penetrate the defecated juices steadily in the form of bubbles which become smaller and smaller while the juices become more and more fluid. The frothing then ceases entirely, and finally a juice is obtained which has a precipitate that is deposited easily and rapidly and is readily filtered. Consequently, while a few minutes previous the spoon sample may have been opaque and had a milk-like appearance it may now have a decidedly yellow hue and the precipitate a granulated aspect. The latter tends to separate from the mass of liquor and give a cloudy appearance. When these clouds are separated by a very translucent yellowish liquid the carbonatation should cease at once.

All factories which appreciate the importance of repeated chemical tests having in view the perfection of the operation of carbonatation, so that the juices may be sent to the filter presses not only with great regularity but also with an alkalinity determined in advance, make an examination of the contents of each tank. The spoon test mentioned in the foregoing is only a preliminary to the more thorough analysis that should follow. The most desirable and rational final alkalinity varies from 0.07 to

0.10 per cent, with phenolphthalein as an indicator, or from 0.09 to 0.12 per cent of lime with rosalic acid as an indicator. However, as in some factories the juices are very impure it is desirable to keep the alkalinity between 0.10 and 0.15 per cent, using the phenolphthalein test.

**Emptying and cleaning the carbonatators.**—The carbonatating tanks should be entirely emptied of their juice after saturation so as to leave a maximum capacity for the operation that follows. In order to prevent interior calcic deposits it is desirable to rinse the sides thoroughly with a jet of water. In some factories this is done once a week, or when the carbonic acid gas distributors are cleaned. As this water is run off through the juice pipe the quantity used should be comparatively limited so as not to dilute the juices with which it is mixed.

**Continuous carbonatation.**—In the foregoing the customary method of carbonatation was described, that is to say, carbonatation in each receptacle filled separately with juice. As continuous working always offers certain advantages many experiments have been made of recent years with this method.

The first experiments with continuous carbonatation were those of Schultz in 1863. He claimed that excellent results were obtained by this method with the ordinary carbonatation tanks. The Barbet combination was among the first to be accepted in practice. In this the juice entered on top of the carbonatator, passed over a series of heating tubes, and then by various stages circulated on a series of slanting planes, coming in contact with the carbonic acid that moved upwards. Then it came in contact with the bottom steam coils a second time and flowed upward to be emptied into another receptacle with a central pipe. The juices fell to the bottom of this receiver and were subsequently decanted.

The Reboux mode was quite extensively adopted in Belgium (Fig. 193). Its extreme simplicity and compactness are important characteristics. The space it occupies is not more than one-fourth that needed for carbonatation tanks as now used.

The apparatus consists simply of cast-iron pipes *T* of about eight inches interior diameter. The slant given to these pipes facilitates the flow of juice and gas, both of which enter at the bottom and escape at the top. When the juices leave the top they, with the scums, fall into a gutter *N*, that carries them to

a filter press. The flow of juice and gas is regulated by suitably-arranged valves $V$.

Gas is introduced at the first junction of the slanting pipes. The juice is limed in a tank placed at a considerable elevation above the carbonatation apparatus; this gives sufficient force by gravity

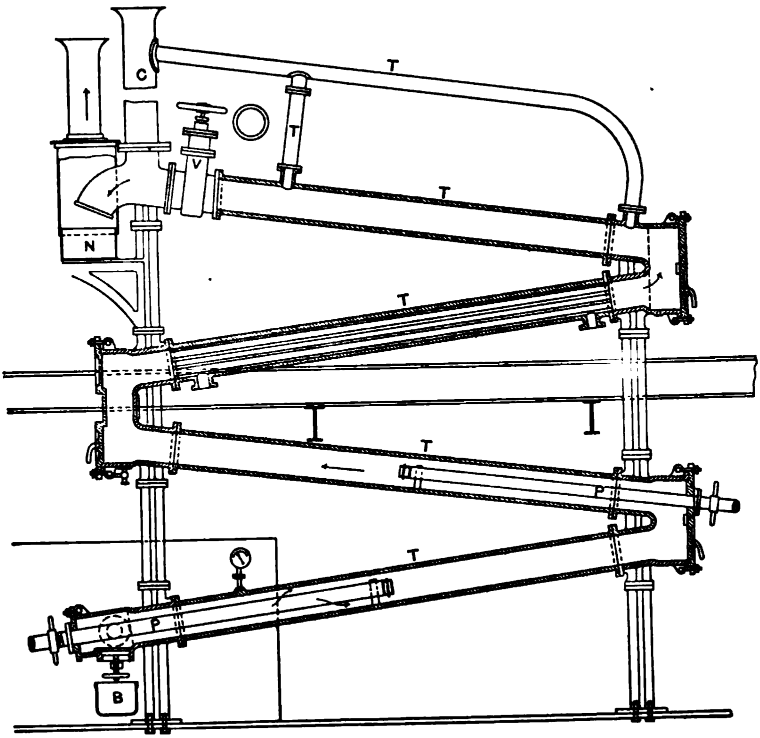


FIG. 193.—REBOUX Continuous Carbonatator.

to assure a perfect circulation. The pipes may be cleaned by water running through from the top.

The pipes were shaped with a view to forcing a closer contact between the gases and the juice, thus obtaining a better utilization of the former. The idea was not successful owing to the impossibility of obtaining a regular alkalinity. At the exit pipe the juices were sometimes insufficiently and sometimes excessively carbonatated. It has been frequently overlooked that in order to obtain a regular alkalinity it is necessary to conduct the operation of carbonatat on upon a large volume of juice, as the nature of the gas and the percentage of lime in juices vary considerably. The

best results from continuous carbonatation have been realized with very simple appliances by continuously running the defecated juice into an ordinary carbonatator with a satisfactory gas distributor. From this receptacle the juice flows through a special overflow pipe to a second tank, into which the carbonic acid necessary to produce the requisite alkalinity is introduced, the juice is then pumped out. The best practice, however, seems to favor a third carbonatating tank. There is a continuous overflow from this tank corresponding to the volume entering it. This last receptacle may be replaced by a reheater, which idea was strongly recommended by ZSCHEYE.*

Continuous carbonatation by the WOLFF method is conducted in three compartments, in the first of which is placed the pipe through which the juice is distributed. Another pipe is used for distributing the milk of lime. By cocks on these pipes that amount of milk of lime shown in the laboratory to be necessary for the complete defecation of the juices is allowed to enter. In the first compartment there is a small steam injector which maintains a sufficient agitation to prevent lime from being deposited. The limed juice runs through a special overflow into the middle compartment into which carbonic acid is injected, so as to nearly complete the operation of juice carbonatation; however, it must be noticed that the operation is really completed in the third compartment, into which the carbonic acid enters and where the desired alkalinity is obtained. At the beginning of the operation there is considerable frothing of the juices in the second compartment, but as the operation continues this subsides, notwithstanding the fresh limed juice entering, which only counterbalances the action of the carbonic acid so as to retain this condition of saturation. When the valves are thoroughly regulated the apparatus needs no further looking after, other than an occasional laboratory examination. This arrangement permits the use of a carbonic-acid distributor, perforated with very small holes, which increases considerably the efficiency of the carbonic acid, and as the operation is continuous the holes do not become clogged.†

Among the other appliances which give moderately satisfactory results mention may be made of the St. Quentin system (Fig. 194). This apparatus consists of sheet-iron receptacles, the

* Z., 50, 361, 1900. † Z., 50, 636, 1900.

length and size of which vary with the position it is to occupy. An external view is shown in the illustration. It is rather high and narrow, the higher the better, so as to contain juice to a depth of 3 to 3.5 meters, thus obtaining the greatest possible efficiency from the carbonic acid. The bottom of these carbonatating tanks has a double slant corresponding to the direction in which the

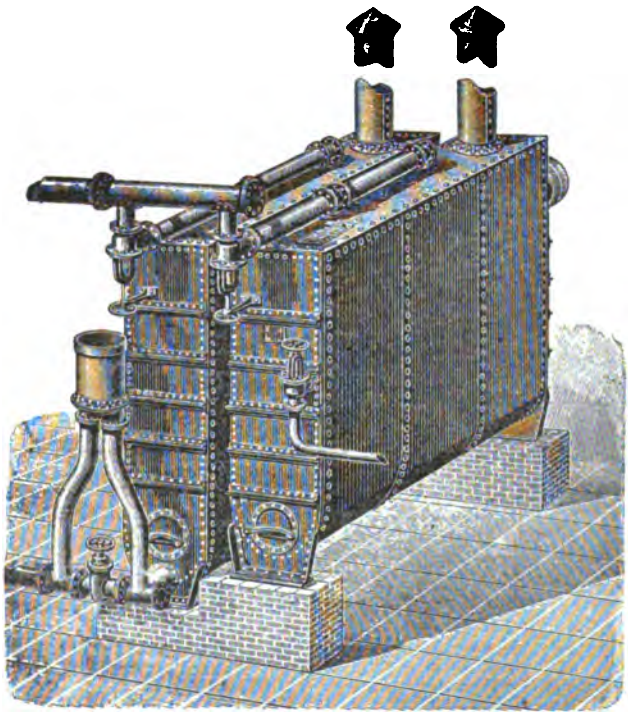

FIG. 194.—ST. QUENTIN Continuous Carbonatator.

juice is displaced. The first carbonatation takes place in two connected compartments. The limed juice enters through a valve placed at the head of the first section; after circulating its entire length it enters the second section through a bottom opening; on leaving this compartment the carbonatated juice rises into a small receptacle, where its level is regulated by a special overflow appliance, and from here it runs into the tank of turbid juices.

During the continuous carbonatation the carbonic acid gas has a free flow into the first compartment, in which there is a mechanical froth arrestor. The saturation of the juice is nearly

completed before it reaches the second section, which is mainly used for regulating purposes, the gas being allowed to enter in quantities sufficient to obtain an alkalinity determined in advance.*

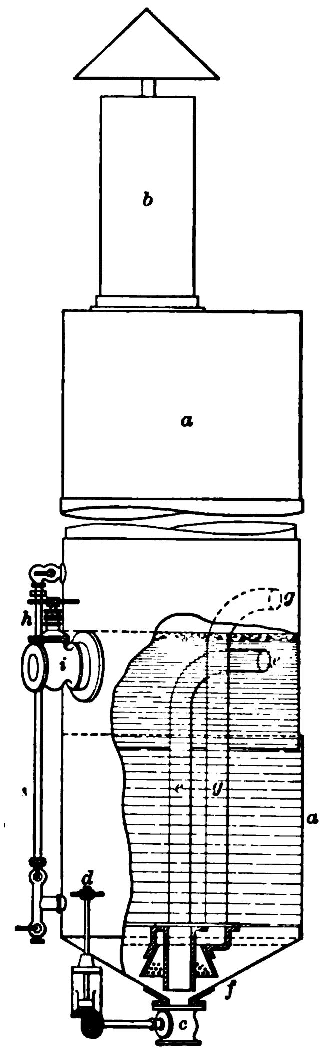

FIG. 195.—NAUDET Continuous Carbonatator.

NAUDET (Fig. 195) has been able to effect a continuous carbonatation in a single saturating tank into which, by means of special floats, there is introduced exactly the same quantity of limed juice as there is carbonatated juice leaving the apparatus. It was noticed that juices at different stages of carbonatation occupy a different volume; these differences of volumes have also an influence upon the floats, and as the apparatus is regulated for a given alkalinity, these floats allow more or less limed juice to enter the carbonatator, the volume depending upon whether the saturation is deficient or in excess. This carbonatator considered separately offers no special characteristics, except that the juices are introdued through *e*, the carbonic acid gas enters through *g*, and they combine in the distributing cone *f*. The carbonatated juice runs in a continuous stream through *i*, and the level indicator *h* permits one to watch carefully the progress of the carbonatation.

By this method the first stage of the operation is an ordinary carbonatation, after which the tank is filled to a certain level and the desired degree of carbonatation is reached. From this time onward the exit valve *i* is kept open and the juice being carbonatated is kept at

* S. B., Jan. 1901.

an almost constant level by introducing through *e* and *g* the limed juice and gas in the desired proportions.

Numerous special appliances have been brought forward, all claiming advantages for the continuous carbonatation, and among these is the Horsin Déon apparatus which had a temporary success (Fig. 196). The carbonic acid, the limed juices

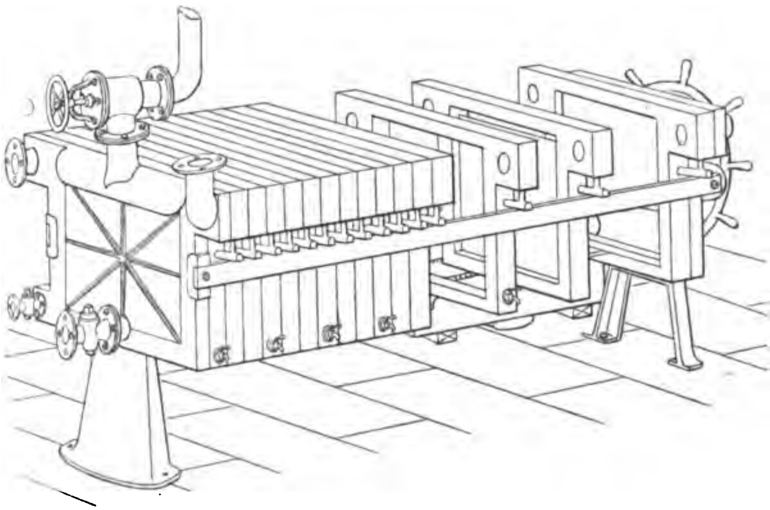

Fig. 196.—Horsin Déon Continuous Carbonatator.

and steam for heating, all enter the apparatus at one end through a cast-iron plate resembling that of a filter press. Thé gas escapes from the top, while the juices, which are subsequently to be filtered, leave the carbonatator by the last frame or division. The circulation is such that the limed juices and carbonic acid gas circulating in the same direction are brought in contact in the various compartments. The gas drives the juice forward four times and in each case bubbles up subsequently into four wider chambers through the juice under pressure. The frames of the apparatus are much the same as those of a filter press, and it is claimed that very little cleaning is needed. The essential point in continuous carbonatation is to maintain the same alkalinity all the time, so that the filter presses will work with the desired regularity, and thus give the results expected. By careful regulation of the circulators of both carbonic acid gas and juice satisfactory results may be obtained. The same degree of alkalinity can be maintained only through constant watching and repeated analysis.

This regular and continuous working depends upon the equal liming of the juice, especially when the operation commences. In order to realize the latter the lime and juice mixers should be of considerable dimensions, of sufficient capacity, for example, to hold the juice of six diffusors. Continuous carbonatation offers one important objectionable feature, namely, it is influenced very much more by any irregularity in the factory's running than in the simple carbonatation. On the other hand, there are certain decided advantages that must not be overlooked. The labor is less for conducting the operation so as to attain a given result; the frothing is almost entirely eliminated; and owing to the limited time in which the juices remain in contact with the carbonic acid gas there is little or no clogging of the gas-distributing pipes. Because the operation is continuous the loss of carbonic acid, according to MALANDER, may be said to be reduced to a minimum, and as a result the safety-valve attachment never whistles on account of escaping gas as it does in the case of other modes of carbonatating.

**Perturbations during carbonatation** are generally caused by a prolongation of the operation, and for this there are many reasons. It is evident that for a rapid carbonatation the gas should be very pure, as there is then a larger absorption than with an impure gas. If the perforations of the gas-distributing pipe become clogged the carbonatation will last longer, which shows the importance of watching these variations and of overcoming the difficulty immediately by proper cleaning. It may also happen that the chimney through which the gases escape becomes so clogged with lime deposits that as its section is reduced to such a proportion that it is no longer sufficient to permit the uncombined gas to make its escape. As soon as this difficulty arises it is important to make a preliminary effort to scrape down the sides so as to leave a passage of at least 15 cm., and to continue the cleaning at the first opportunity that presents itself during a stoppage of the factory. The deposits may be loosened by repeated striking on the outside of the chimney with a mallet, and as they are frequently of considerable size and may fall several meters it is advisable to place boards at the bottom of the carbonatators to prevent their being broken.

**Excessive frothing.**—An excessive frothing of the juices, which is also the cause of serious perturbations, depends upon the nature of the beets and the manner of working the battery. It occurs

simultaneously with a poor carbonatation. Frequently certain juices tend to froth very much more than others, especially when the beets were partly rotten or frozen when entering the slicer, and the best practical remedy seems to be to fill the carbonatation tank only partly. This frothing, in exceptional cases, may become so excessive as to make it impossible to open the entrance valve for the carbonic acid gas. If the frothing is such that the space allowance above the juice level in the carbonatation tanks is insufficient the only remedy is to add an ample amount of oil or other fatty substance as a froth arrestor.

**Slow carbonatation.**—Besides these causes, which may be readily determined, there are other reasons for slow carbonatation, which may possibly have some relation to the composition of diffusion juices, but no satisfactory explanation of this point has yet been given. However, it appears possible that the pectic substances play an important rôle, as a poor carbonatation, caused by the inferiority of diffusion juices, shows itself during the working of poor beets, for instance, such as were harvested before maturity or cultivated with an excess of fertilizers; or it may depend upon the manner in which the operation of diffusion has been conducted. When pectic substances are in excess they appear to combine with the lime and thicken the juice in the same manner as does the sugar, but the thickening is then more difficult to get rid of, and as a consequence the carbonatation is not satisfactory. It is desirable under these circumstances to mokify the working of the diffusion battery so that the operation may have the shortest possible duration and be conducted at a reasonable temperature. Whenever the carbonatation is of long duration, from one cause or another, the quality of the juice suffers, not only as to color but also in purity, and for that reason one should always determine the cause as soon as possible and overcome the difficulty.

When the carbonatation is too slow, or lasts too long, it may be due to juices that have been excessively limed, or the milk of lime used may have been too thick, or quicklime may have been added to an excess.

**Quantity of lime.**—It frequently happens that through some oversight double the requisite amount of lime is added to the juice of a diffusor. When the juices are to pass through a mixer the mistake is evidently less serious owing to its coming in contact with five times more juice; however, should the quantity of lime used be very much in excess of what it should be the difficulty may be

overcome by sending to the measurer the juice from a diffusor that has not been limed.

On the other hand, if it is noticed that the juices have not sufficient lime and that the operation of carbonatation is very short, one may add to the juices in the mixer a small additional measure of milk of lime and increase the quantity for the measurers that follow. The activity of the carbonatation may be decreased owing to the tank being too full, as shown by the excessive frothing, or may be the outcome of either some neglect on the part of the carbonatator man or faulty working of the valves.

**Valves.**—MALANDER insists upon having the seats of these valves thoroughly tight and in satisfactory working order. If the entrance valve is leaky the juice will reach an abnormal level in the carbonatation tank and will froth over the sides. These difficulties are always to be feared when the receptacles are too full. Either the gas pressure will be unable to overcome the height of the column of juice, or the carbonatation will be retarded and the frothing be excessive. The faulty carbonic-acid valve may result in numerous complications, and, furthermore, there is danger of suffocating the person in charge of the inside cleaning after the receptacle has been emptied, and under no circumstances should the cleaning ever be done when the gas pump is working, unless the gas is allowed to escape through the safety valve and a blank flange is put in the distributing pipe.

**Cleaning.**—In most factories visited by the writer it is customary to resort to the lighted-candle test; if when lowered to the bottom of the tank the candle remains lighted it is presumed that there is no danger. Experts declare that a certain quantity of oxid of carbon may remain at the bottom, which is even more dangerous than carbonic acid, and the only way of overcoming it is by some kind of ventilation. Under no circumstances should the carbonatation be started before making sure that none of the men are at the bottom of the tanks in a semi-suffocated condition, and as long as the cleaning lasts the superintendent should never lose sight of his men.

Notwithstanding the precautionary measures taken during the campaign to keep the saturating tanks thoroughly clean, a thick and hard calcic deposit is formed on the inner surface of the receptacle. These deposits may be removed by scraping off with a chisel, but of late years other modes have been suggested.

Very satisfactory results have been obtained by washing the

carbonatation tanks with boiling water, to which has been added a small quantity of hydrochloric acid. This is then run through a filter press, the frames of which are covered with old cloths. The liquid on leaving these is neutral. It is recommended also to prepare a sodic solution in the evaporating appliance. When the triple or multiple effects are sufficiently clear, the sodic solution used is run into the carbonatating tanks, pumps, filter presses, etc. This work lasts only a few hours, and is more effectual than the old method of cleaning, demanding several weeks.* Without doubt one of the objectionable features of this method is that it causes considerable wear on the weaker portions of the filter presses, etc.

**Mistakes made.**—If, as it sometimes happens, the carbonatation has been pushed to an excess, the only remedy is to raise the alkalinity of the juice beyond the limit that the standard experience has shown to be the most desirable, and to recommence the carbonatation, continuing it until the desired alkalinity is reached. If this precaution is not taken and the excessively carbonatated juices are run through the filter presses, their cloths will soon be clogged and considerable time must elapse before normal conditions can be established. In order to raise the alkalinity of the juice either milk of lime, powdered lime or limed juice may be added. Another mistake that is of too frequent occurrence is that the contents of the carbonatating tank is run through the presses before the saturation is completed. The filter presses are at once put out of order and it takes hours to clean them.

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* Z., 48, 965, 1898.

## CHAPTER IV.

### FILTER PRESSES.

**Decantation.**—When carbonatation was first introduced considerable difficulty was experienced in handling the large quantity of resulting scums. In order to gain time and save the cost of expensive filtration plants, efforts were made to separate a portion of the precipitate from the carbonatated juice by decantation. The illustration herewith (Fig. 197) gives an excellent idea of the arrangement of the LECOINTE & VILLETTE carbonatation boiler and decanting vats. The boiler has a slight inclination towards the decanting vat. The emptying cock is placed outside the decanting vat to send the clear juices into a different tank from that receiving the turbid juices. The pipe connecting said cock with the interior of the decanting vat is flexible, and is attached to a suitable float; the result is, that when clarified juices are present they are the first to flow off. The boiler and decanting tank are placed in communication by raising the stopper of the connecting tank.

Later fault was found with this mode, and it was shown that it was not continuous in operation. In the large sugar plants as they now exist such a method would not be desirable. Numerous continuous decanting combinations, such as the VOLTER, have been patented, but few if any of them have much practical value. However, the idea of decantation has been recently taken up again, but upon a different basis. Instead of a moderate pressure exerted upon the juices by the force of gravity centrifugal force has been employed.

Among the first appliances of this kind, which, however, did not render the services expected of it, was the POLACZEC * apparatus consisting of a horizontal centrifugal. Better results were ob-

* Oe.-U. Z., **23**, 643, 1894.

ained with the Hignette decanting centrifugal (Fig. 198). It is claimed that all the substances in suspension and the precipitates, either mineral or vegetable, as well as gum-like products, are eliminated in one continuous operation. This apparatus, as

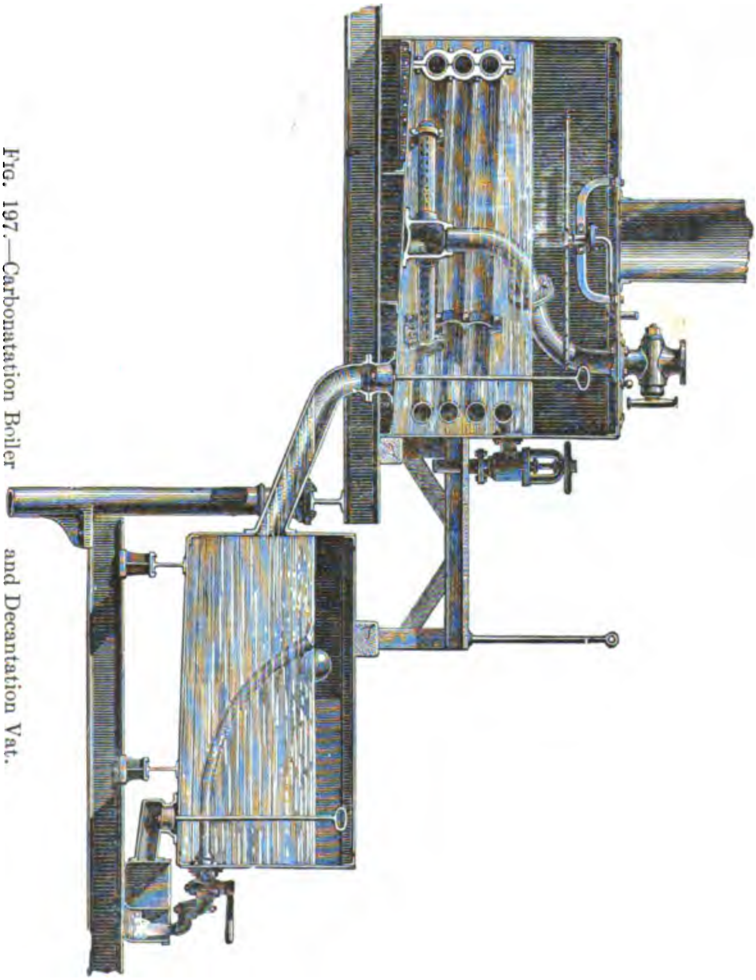

Fig. 197.—Carbonatation Boiler and Decantation Vat.

shown in the illustration herewith, consists mainly of a drum revolving at a known velocity. The drum itself is of steel, but instead of being covered with some gauze or filtering material it has no opening through which the juice can escape. At the upper part of this drum and inside is an annular diaphragm held

in position by supports placed at regular intervals. The juice to be decanted is brought to the lower part of the drum. By the centrifugal action the scums, heavier than the juice, are precipitated on the sides of the revolving drum; as they possess a certain viscosity they rise to an upper level, and at a given moment appear above the diaphragm, from which position they are collected through a special nozzle shown in the figure. The clear juice, on

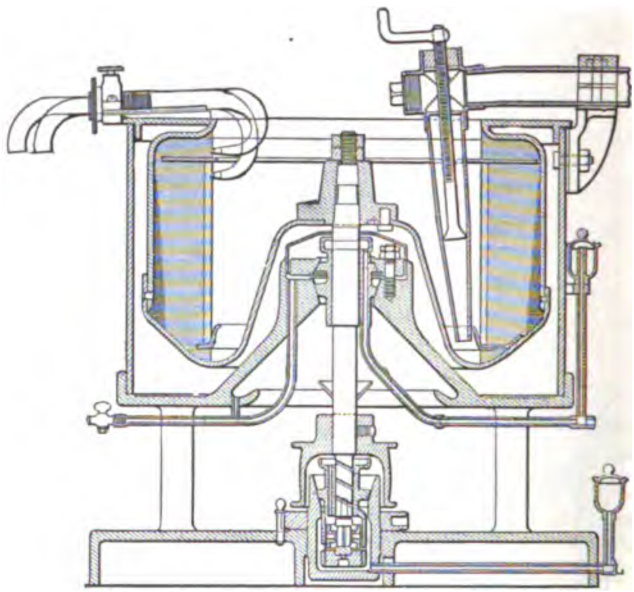

FIG. 198.—HIGNETTE Decanting Centrifugal.

the other hand, being lighter, remains near the centre of the drum and is collected through a second nozzle. The scums must be removed when the juice running from the apparatus appears in the least turbid. The motion is given from below. These centrifugal decanters, with drums of 1.20 meters in diameter, may be worked by electricity. At the present time the filter presses are used almost exclusively for separating the particles in suspension. The juice is sent directly from the carbonatation tanks to the monte jus, which forces it into the filter presses, or into a waiting tank, from which a pump forces a circulation through the filter presses. The waiting tank may have any shape, but its capacity should be limited. It should not have a volume greater than that of the carbonatation tank, as otherwise the

carbonate of lime would soon settle on the bottom and cause complications. Furthermore, the juices are too rapidly cooled in a large receptacle. The surface float should have two pointers, plainly visible to the carbonatating man and the person in charge of the scum pump, and they must be constantly watched. The closed tanks have an exit-air vent, the height of which must be greater than that of the maximum level of the juice in the carbonatating tanks. It is still better to have this exit in the chimney of the carbonatating tanks, as by this arrangement the froth that is frequently carried forward with the air simply falls into the carbonatating receptacle. The pipe connecting with the safety valve of the force pump should terminate in the waiting tank. In this case the juice, if for one reason or another it ceases to travel in the direction of the filter presses, will return to the tank from which it was taken.

The waiting tanks should always have a suitable manhole for the removal of deposits, such as lime, sand, etc. Between the waiting tank and the force pump is placed a gravel separator, much like the pulp-arrestors connected with diffusion. If such impurities were allowed to remain they would soon wear away the working parts of the pump, and form serious obstructions in the narrow passages of the scum presses. It is desirable to have a basket in reserve so that when one is filled with these impurities it may be replaced. The contents should in all cases be carefully examined when the scum pump is working irregularly.

While some beet-sugar factories continue to use the **monte jus** they are rapidly going out of vogue. Though they render excellent service there cannot be the slightest doubt that scum pumps are preferable. The monte jus shown in Fig. 199 consists of vertical, hermetically-closed, sheet-iron cylinders *A*, an entrance valve for the carbonatated juice, a pipe *D*, which passes through the centre of the cylinder to within a short distance from the bottom and through which the juice is forced to the filter presses. The valve *L* is for steam, and *N* is the manhole for cleaning the receptacle. The apparatus works in the following manner: The valve *M* through which the steam makes its escape is open and all the other valves are closed; the juice valve *C* is opened and the apparatus is filled with juice, after which this valve is closed and also the escape-steam valve; the exit-juice valve *E* is opened. Then live steam is slowly introduced through the valve *L*, and the pressure exerted forces the juice upwards into the pipe *G*

in the direction of the filter presses. Upon these monte jus there should be safety-valve attachments regulated so that they allow the steam to escape as soon as the most desirable pressure for the filter presses is reached.

There are many practical means of ascertaining when the monte jus is empty, among which is the characteristic sound made by the steam entering the force pipe. But this warning comes

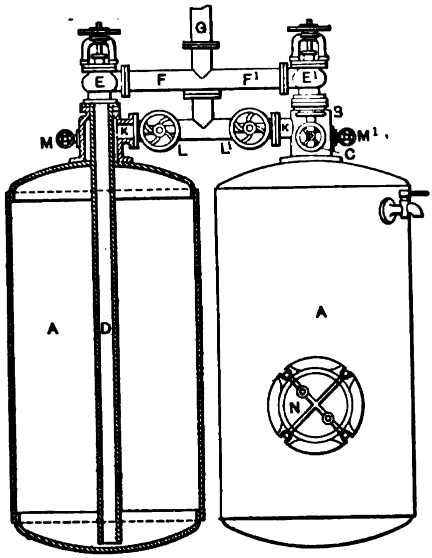


Fig. 199.—Monte Jus.

too late, as steam will already have caused some damage in the filter presses. To overcome such difficulties a float can be placed in the monte jus, which gives an alarm signal as soon as the juice in the interior of the apparatus is below a certain level. When the monte jus is emptied of its juice the valves *E* and *L* are closed and *M* is opened. There are many advantages in not allowing all the steam in the apparatus to be lost after each emptying; hence it is allowed to escape into the exhaust-steam collector of the factory. When finally the pressure is no longer sufficient to force the steam into the receiver it is allowed to escape through the purge cock.

Experience shows that filter presses generally work satisfactorily when in communication with the monte jus, for the reason that the juices enter hot and the pressure is very regular; but its intermittent working is an objectionable feature. Efforts have been

made to overcome this difficulty by the construction of an automatic monte jus.

**Automatic monte jus.**—The SCHULZE * apparatus receives the juice from an upper-pressure tank, placed at an elevation of one meter, so that the pressure exerted is sufficient to open the feeding valve. The entrance steam-valve is worked by a double float that opens the valve when reaching the upper level and closes it when at the bottom. When the steam-entrance valve is open, the exit-steam valve is closed, and vice versa. The juice consequently opens the entrance-steam valve when the monte jus is filled, and will be immediately emptied. As the pressure in the apparatus is entirely removed the juice from the reservoir will open the feed valve and fill the monte jus up to the second floating level.

One great fault to be found with the monte jus is, that the temperature of the steam used as pressure is frequently sufficient to affect an alteration of the sugar. Also, notwithstanding the fact that there are means of reducing the volume of steam lost, the consumption is very much greater than it should be. As has been pointed out, some steam is lost by escape through the purge cock into the air, and still more is condensed when it comes in contact with the juice. Although this cannot be considered entirely lost, as it furnishes a certain number of calories, there are other ways of attaining the same results, which are certainly more economical, for instance, as explained under the caption of reheaters, the use of the exhaust-steam from the engines, etc., with the further advantage that the juices are not then diluted.

The pressure at which the juices are forced into the presses should not exceed a certain limit. The faulty handling of a monte jus invariably results in steam entering the filter-press frames where it burns the cloths or rapidly wears out the frames. In order to overcome this difficulty SCHULZE (Fig. 200) uses a small box *A*, which communicates with the monte jus through *B*, and with the filter presses through *C*. The float *D* has two valves, *F* and *G*. When the monte jus is to be emptied the float is raised by drawing it upward by an exterior handle. The valve *G* is then closed, *F* is open and the juices find their way through *C* to the filter presses. As long as these juices are running they keep the float *D* suspended, pressing it on *G*. As soon as the

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* C., **11**, 217, 1902.

circulation ceases the float drops, all communication between the monte jus and the presses ends and a small jet of steam then escapes through *E*.

Efforts have repeatedly been made to do away with steam in the monte jus and to use compressed air instead; but appliances

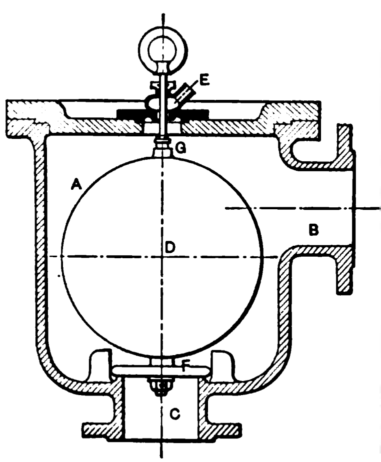


FIG. 200.—SCHULZE Safety-valve.

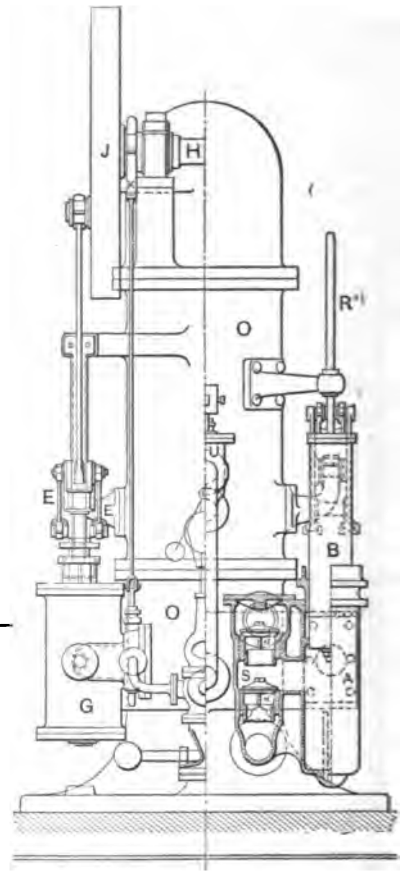


FIG. 201.—CAIL Vertical Pump.

with this object in view have not all the advantages of the former arrangement. The plant consists of an engine or some other device for transmitting power, an air compressor and a receiver having twice the capacity of the monte jus. The compressed-air monte jus generally holds the contents of half a carbonatating tank, that is to say, its capacity is about equal to that of a diffusor.

Under these conditions two monte jus are sufficient for the working of an average sugar plant. In most cases, as mentioned in the foregoing, the carbonatated juice is sent to the filter presses by a scum pump.

**Scum pumps.**—There are many types of these, but all work on the same general plan with a plunging piston. They are either vertical or horizontal, the former appearing to last the longer, and are of single or double action.

The vertical-scum pump shown in Fig. 201, of the CAIL model, is a single-action pump. The plunger *B* receives its motion indirectly from the steam-engine *G*. This piston draws the juice up by suction through the valve *a'* and forces it through the valve *a* upon the downward stroke into the filter presses. The large receiver *O* acts as an air-cushion and pressure regulator. The stuffing-boxes used with these pumps are frequently responsible for many difficulties. Do what one may, there appears to be no way of making them perfectly tight, and if some precautionary measure is not taken to collect the juice that escapes through these badly-constructed spaces important losses will follow. If the packing is abnormally tightened the resistance offered will soon be too great for the piston to overcome, for the simple reason that as the plunger is exposed to the air after each stroke it becomes more or less covered with a calcareous deposit causing ultimately an increased diameter. Within reasonable limits this difficulty may be overcome by repeatedly sprinkling the plunger with water as it leaves the packing or stuffing boxes, but this is objectionable on account of the difficulty of securing cleanliness. Furthermore, one never knows just how much juice is being lost in case there is an escape through the stuffing box. Considering all these facts, this form of pump does not seem well adapted to the work in view.

On the other hand, with the double-acting pumps and interior packing these difficulties may be overcome.

**Packing of piston.**—In this case the piston has no outer packing, but the cylinder is made up of two parts beveled like a regular stuffing box. One-half of the cylinder is movable and has the shape of a sleeve. Between these two halves of the cylinder a rubber ring is placed which the movable portion presses against the piston by means of two tightening screws passing through the cover of the cylinder. The packing may be tightened from the exterior. The juice thus has no means of escape, and in case of leak-

age passes from one side of the piston to the other. In the German pumps as made at Halle (Fig. 202) the piston *a* is made tight in the cylinder in which it moves by a rubber or white-metal sleeve *b*, which is pressed against this piston by a suitable ightening ring. In certain pumps made at Brunswick the ring may be tightened from the outside. A glance at the drawing will show that if there is an interior leak in the sleeve *C* the liquid passes from one side of the piston to the other without exterior leakage.

The valves of scum pumps should be readily taken apart as the seats frequently become clogged with a lime deposit, resulting in a faulty working of the pump. Upon the force pipe connecting

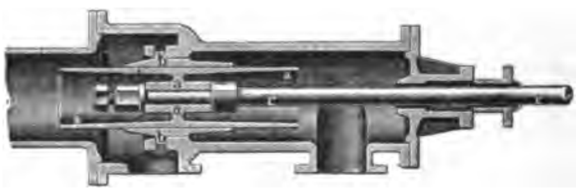

FIG. 202.—German Pump.

with the pump there should be, as shown in *O* (Fig. 201), an air receiver and pressure regulator. The constant working of these pumps obviates in a measure any lime deposits or other clogging. In such cases a safety valve must be used upon the pipe leading to the filter presses. In an emergency the escaping juice simply runs into the waiting tank of cloudy juice.

**Pressure.**—MALANDER recommends that the safety-valve in question be regulated for a pressure of 1.5 atmospheres, and that this be increased by one-tenth of an atmosphere for each meter of difference in the level of the filter presses and of the pump. On the other hand, CLAASSEN points out that the pressure at which the pumps should work depends upon the size of the filtering area of the presses and the nature of the scums. It is desirable for the pressure to be about 2 or 3 atmospheres, as the scum cake thus formed is readily exhausted of its sugar. With poor scums and small filtering surfaces the pressure should vary from 4 to 8 atmospheres. A greater pressure would not be desirable as there would be danger of the press compartments bursting as soon as the pressure on one place was greater than that on the other. With a view to keeping the pressure under control it is important to have suitable gauges both on force pipe and on the air reservoir.

The pressure produced by the scum pumps should never be

more than three atmospheres, which is realized by many combinations. HORSIN DÉON says that the diameter of the piston of the steam engine working the pump must be calculated in order that with the highest pressure in the boilers the maximum pressure desired for the scum presses cannot be exceeded. While the air receiver and pressure regulator renders excellent service it is frequently found desirable, in order to still further regulate the pressure, to have yet another device by means of which the force pump may work at a pressure determined upon in advance, and one that, furthermore, will automatically stop the scum pump when the juice valve connecting with the filter presses is closed.

**Pressure regulation.**—The LEGAT regulator (Fig. 203) consists of a balanced valve *D* which special springs keep in position so that the steam working the scum pump may be allowed to pass through the passages *E*, *S*. On the other hand, the juice from the regulator-air receiver enters at *N*. When the pressure is too great upon *N* the valve *D* is forced upon its seats, steam can no longer circulate through *E*, *S*, and the pump will stop. The tension of the spring attached to the arms *B*, *B′* may be regulated by the wheel *A*. This appliance has already given good service.

FIG. 203.—LEGAT Regulator.

In most cases the pressure is regulated by a safety valve under the conditions previously explained. But notwithstanding all these efforts it is impossible to prevent a fall of the pressure in the force pump whenever communication is made with a new press. Consequently these scum pumps do not work with the desired regularity. VOGELSANG places upon the force pipe of scum presses handling juices from first carbonatation an accumulator of juice under pressure. It consists of a large cylindrical receptacle in which the juice forces towards the top a plunger that is so weighted as to exert the desired pressure. If the pressure in the force pipes decreases through the switching on of a new filter press the use of this device presents a compensation. When the working of a new filter press is reaching its limit, that is when

the juice ceases to run off, it forces up the piston of the regulator to a position where it will exert its maximum effect as soon as the filter press is changed.

It is claimed that filter presses may have their capacity increased by an additional pump working at high pressure. The juices are forced into the presses at low pressure, and as soon they run slowly they are forced through by the use of the second pump. It is declared that under these circumstances the filtration is more active, the juice is obliged to pass through but a very thin layer of scum before leaving the press battery, and the filters work for a long time before being full. The relative pressure of the two pumps is determined in advance.

In the force pipe a sluice valve should be placed so as to retain the juice in its interior. This is important in case it becomes necessary to examine the pump during the campaign. It frequently happens that when the scum pumps will not work and the pressure gauge upon the regulator and air receiver indicates a lower pressure than usual, the trouble may be due to a slower action of the pump, indicating that the pipe of communication contains more air than the regulator can handle, and this should be allowed to escape through special purge cocks. The working of the pump should then at once become normal. If it does not the difficulty must be due to other causes, such as leaky valves through clogging from lime deposits. These should be examined, and if the trouble still persists the packing of the piston or the stuffing boxes should be looked after.

**Filter presses** consist of a collection of frames and disks between which two or four sheets of filtering cloths are pressed. The carbonatated juice is brought to the centre of each group of two or four cloths and forces its way through the tissue, leaving upon its surface the particles held in suspension in the juice which escapes from the interior of the frames to the exterior.

The first filter press was invented by NEEDHAM* in 1853, and in 1856 he and KITE introduced an apparatus not unlike the modern one, but made of wood. The numerous presses that have since come into existence cannot all be reviewed here. They all have iron frames with a pressing plate at each extremity, which may be either square or round.

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* Jelinek, Reinigung, p. 30, 1864.

**Frames and plates.**—The compartments consist of large square disks having partly raised borders so arranged that there is left sufficient space between two disks for the scum to collect. The exterior surface of these disks is formed of two perforated sheet-iron plates between which the filtrate collects. Between the two cloths are raised portions to hold up the filtering material. Sometimes these perforated portions of the iron plates (Figs. 204 and 205) are done away with, and the surface of the plates is undulated so that the juice may readily run off from the bottom of the plate through a special exit hole. The carbonatated juice enters at the centre. Through the opening passed a nipple to hold up the filtering cloth which has also a hole in its centre. As a general thing two cloths are placed on each frame.

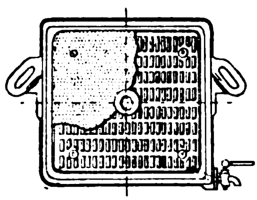


Fig. 204.—With perforated Plate.

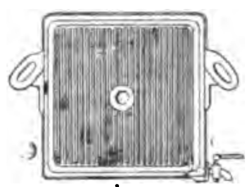


Fig. 205.—Grooved Disk.

By pressing one frame against the other the outer border presses the cloths and forms a joint. By this arrangement there exists between two disks a free space enclosed by the filtering cloths which receive the juice from the centre, thus forming one continuous passage communicating with a series of pockets. The juice passes through the cloths then through the perforated-iron disks and finally escapes from the press by small passages arranged in the thickness of the disk. The central opening is continuous, and at each disk a cock is placed through which the juice flows into a trough. The separated precipitate, called scum, remains on the cloths.

This arrangement has some objectionable features. Riedel * placed the entrance opening for the juice on the top of the frames, and later it was located entirely outside of them, in the projecting ears. This new departure demanded an entirely new construction of the disks and frame attachments. The disks were as formerly covered with double-filtering cloths, but with each disk alternated a frame, and thus each frame was pressed between two

* Z., **14**, 642, 1864.

disks. The principal object of the frame was to provide sufficient space for the scum to deposit and for the cloudy juices introduced through the passages *A* and the communication *B*, existing in the thickness of the frames. (Figs. 206, 207, and 208.) The frames and the disks have several ears in which are one or several passages *C* for the water or steam used for scum washing. Fig. 206 shows an ordinary disk upon which the scum is deposited. The filtered juice passes through the opening *E* and the cock *F*. The same conditions exist in the case of the disk shown in Fig. 208. It is customary to alternate the disks in filter presses with the frames in the following manner, II, I, III, I, II, I, III, etc. When the scums are to be washed of their sugar the passage for the cloudy juice is closed, also the cock *E* of disks III and the whole passage for the water is opened. The water passes by the canal *C* and the communication *D* into the interior of III, then through the perforated iron plate, the filtering cloths and the scums deposited

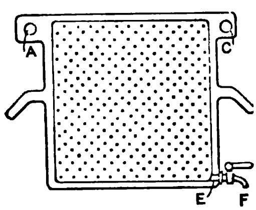


FIG. 206.—Disk II.

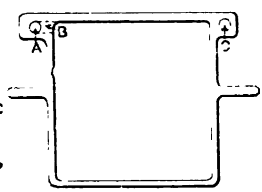


FIG. 207.—Frame I.

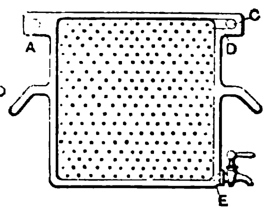


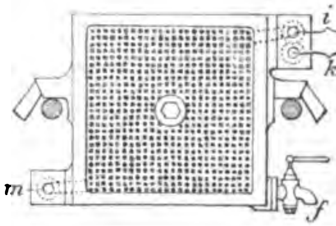
FIG. 208.—Disk III.

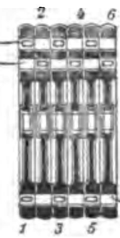
on either side of III. It carries with it the juice that has been held back by the scums and passes through the scum cake, the cloths and the perforated disk on the other side to enter the disk II from which it escapes to the exterior through *E* and the cocks *F* which have remained open.

Figs. 209, 210, and 211 show the DEHNE arrangement for scum washing where the juice is introduced through a central canal. Here also one must make a distinction between the even and uneven numbered frames of the series. After the entrance passage for the cloudy juice has been closed the cocks *f* are also shut, and the water used for washing is introduced into the interior of the uneven numbered frame through the canal *m*. The air is then allowed to escape through *i* when this passage is closed, and the water runs from the uneven frames and passes through the perforated sheet iron and the scum into the even numbered frames, escaping through the canal *K*. In connection with

filter presses with disks and frames there are many devices for permitting the escape of the air and the entrance of the water. When water or compressed air is used in filter presses they may be introduced either through the water or juice passage, or through a separate canal.

In the compartment types the juice passage is placed in the centre and the filtering cloths are made tight by a system of nipples. They have the advantage of being tighter at the borders, as the joint consists of four thicknesses of the filtering cloths. The main objection is that considerable time is necessary for their mounting and unmounting, and if this is not properly done and the cloths are not straight their efficiency will be considerably



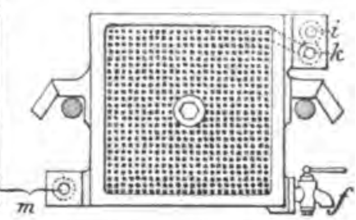




FIG. 209.—Water Disk. FIG. 210.—Cut. FIG. 211.—Sweet-water Disk.

lessened. It is for this reason that preference seems now to be given to presses with frames in which the cloths are simply applied against the sides as they may then be adjusted in a few minutes. One of the objectionable features of these presses is leakage, especially under excessive pressure, but this difficulty may be readily overcome by experts who understand the importance of keeping the frames clean and free from adhering scum, and are careful to keep the cloths well and evenly stretched when the frames are being placed in position, one against the other. Whatever be the complication, it is noticeable mainly during the first period of the work.

The frame filter presses present another difficulty which is that the passages for the cloudy juice in the interior of the frames frequently become clogged through scum deposits, and as there is always some difficulty in cleaning this passage it has been proposed to introduce into the canal a small movable portion, which when taken out leaves sufficient space for the introduction of the scraping brush. This adjustable part is dovetailed so that it may not become loosened during the working of

the press.* Many other combinations have been tried with the same object in view, but they were never generally introduced. The frame filter presses and those with disks each offer certain advantages and certain objections which will be subsequently examined.

**The size of the filter presses,** that is to say their capacity and the number of their compartments, is proportionate to their efficiency. The press should permit of continuous work. It is a mistake to run a large press for a small production, or with a series of small ones, as the production cannot meet the filtering capacity of the large press, and when this is to be emptied the small ones don't meet the requirements. The best way is to have a waiting tank where the juice may remain until needed. In large plants no small presses must be used, as they demand considerable care involving an additional cost for labor and filtering cloths, which is greater than when large presses are used. To work under very satisfactory conditions, not less than three or four presses are needed.

The size of the compartments or frames varies from 60 to 100 cm. square; the number in a press or in a division varies from 20 to 40. In some filter presses, such as the so-called Cizek (Fig. 212) monsters, there are 160 frames arranged in two clusters.†

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* Z., **51**, 845, 1901.

† The frames of the Cizek press are 90 cm. high, 80 cm. wide, and have a thickness of 2.6 cm. The disks are 2.4 cm. in thickness and the frames have rubber joints. Both frames and disks have holes which form a continuous canal when the press is mounted. The lower lateral canal is for carbonatated juice, the two on top are for the water used during washing, and another, a small passage, permits the air to escape. It is interesting to note that the canals in these presses are exceptionally large. One of the important advantages of these large presses is that they are operated by about the same number of men as the smaller ones, and there is, furthermore, very much less work, for owing to their size they need be emptied and filled less frequently, and, therefore, the quantity of cloudy juice, always found when the press is first started, is very much less, and as the pressure in the large presses is much more uniform than in the small ones there necessarily follows an increased efficiency per twenty-four hours. Certain experts declare that in the Cizek press 70 to 80 liters of water are needed for 100 kilos of scums. The advantage of having two canals, one on the right and the other on the left, for scum washing is that the filtering cloths last longer. One of the objectionable features of these large presses is that if any perturbation should occur in the working the very large volume of residuum scums would be difficult to handle.

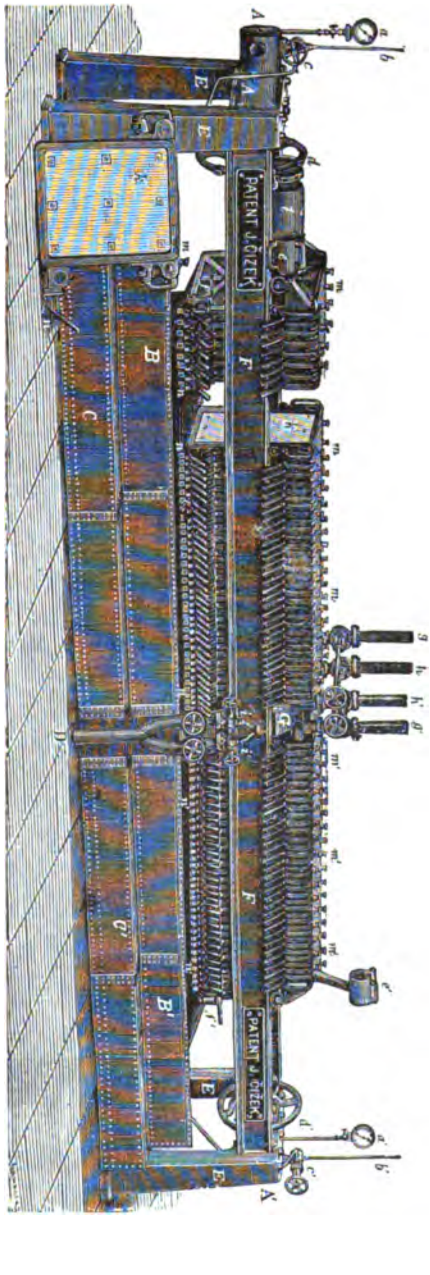


Fig. 212.—Cizek Monster Filter Press.

**Thickness of scum cake.**—The thickness of the scum cake varies from 15 to 30 mm. It is not desirable in the case of poor scums to have any special thickness, but the reverse is true for superior scums, which are readily filtered and the thickness exceeds 30 mm. in some factories.

**Filtering surface.**—No positive rule can be given as to the most desirable filtering surface for a given number of beets per diem, as the filtering properties of scums are extremely variable. However, upon general principles, the largest possible filtering surface should be provided so that it will give satisfaction even with inferior scums, under which circumstances the results will represent a fair average, and with superior scums ample time is allowed for thorough exhaustion. In German beet-sugar factories it is generally admitted that one square meter of effective filtering surface is necessary for 2500 kilos of beets sliced in twenty-four hours. CIZEK says that in a single monster press of 160 frames and disks a filtering surface of 200 square meters is sufficient for a factory slicing 400 tons of beets per twenty-four hours.

**Grooved and perforated sheet-iron plates.**—To give the cloths a satisfactory hold they may be screwed onto the compartments in which they are hung. Of late the surface of the plate is slightly fluted, the wear and tear during cleaning being thus reduced and the necessary number of cloths remaining the same. On the other hand, fault is found with these disks in that their use retards the circulation. The places where the filtering cloths rest upon the iron are evidently inactive, and as the juice can only pass through the holes of the perforated plates the filtering efficiency depends upon their number. Square holes give a larger filtering surface with a minimum loss as regards the resistance of the sheet iron. It does not appear desirable to exceed 4 mm. for the sides of these holes.

**Exit cocks.**—The escape cocks attached to the frames through which the juice leaves the presses may cause trouble. The filtrate of carbonatated juice always leaves behind a deposit which frequently prevents the cocks from closing. Their cleaning is expensive, and after the sugar campaign has terminated they should all be reworked on the lathe. CIZEK substitutes for these suitable flap valves such as are shown in Fig. 213. They may be readily opened by moving the handle $L$ around $a$. The new position $b'$, $c'$ is shown by the dotted lines. The flap valve $cc$ works on a hinge $d$, and the joint consists of rubber plates. It is claimed that

they will last for a long time. Particles of sand always contained in beet juices will cause very little wear and tear, but some experts claim that it is difficult to maintain a satisfactory joint.

A stop cock permitting the regulation of the flow of juice in several directions * may be applied to an ordinary filter. When the filtrate is not sufficiently clear it may be brought back into the filter, forcing its passage into the first compartment. This means a complete double filtration. When the filtrate is satisfactory the cock is turned so that the whole apparatus works on a basis of single filtration.

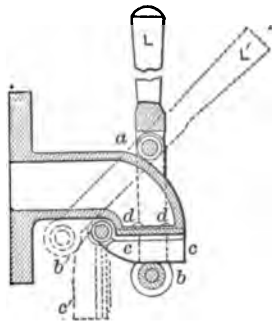

FIG. 213.—CIZEK Flap Valve.

**Supports.**—The frames are supported by their handles on transverse bars, upon which they may slide, while heavy frames run on suitable rollers. These transverse bars are generally round and are held up by suitable supports at each end, in which the compressing device is arranged. To one of the supports is fixed the tightening screw and to the other a disk covered with perforated sheet iron through which the juice, water or steam is introduced. In the monster presses a small steel girder is substituted for the round iron bar supports.

**Tightening of the frames.**—Owing to the careful manner in which filter presses are now made, they seldom if ever break, and by recent methods the joints are made perfectly tight. To effect the requisite tightening various devices have been tried, but a large screw is generally used for the purpose. The end of the screw and also the disk upon which the pressure is exerted should be perfectly flat, otherwise the last frame of the series might be broken by the pressure.

The DEHNE press of this kind is shown in Fig. 214. Very frequently the last frame *A* (Fig. 215) on the side next the screw has a projecting hollow piece *EE*, in order to leave a cavity into which the tightening screw may penetrate. The SCHEIBLER arrangement under consideration offers among other advantages that of permitting the opening of the press without the necessity of loosening the screw over its entire length. When the press

* N. Z., **41**, 211, 1898.

is to be tightened up in front of the screw an iron piece $F$ is placed against $EE$, and by turning the wheel at the end of the screw all the frames of the press are tightly held against one another. In the

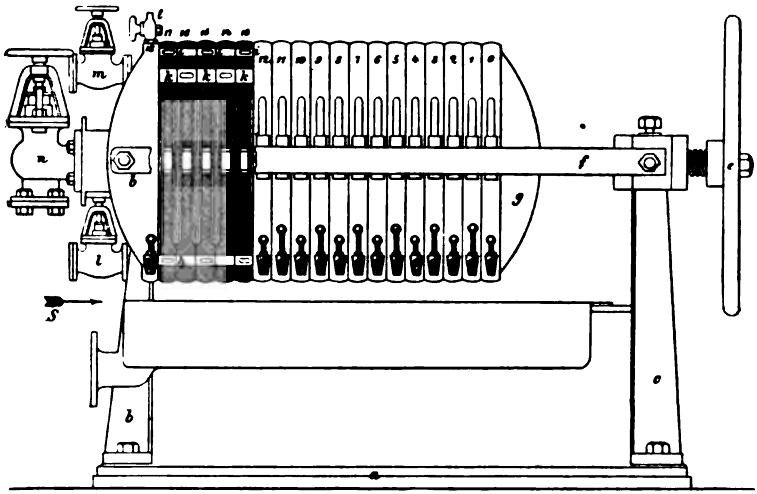

FIG. 214.—DEHNE Filter Press.

KROOG filter press (Fig. 216) the tightening screw $h$ is placed in a movable portion $g$, which may revolve around the pivot $b$. When the filter press is in full activity, the hole $c'$ is placed in front of $c$,

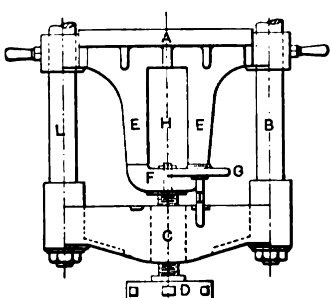


FIG. 215.—Plan of End Frame of SCHEIBLER Press.

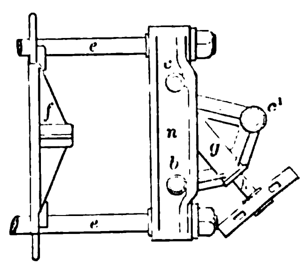


FIG. 216.—KROOG Frame Tightener.

and by means of a pin run through them they are made to form solid mass within. The screw $h$ can then exert its pressure a against $f$. When the press is to be loosened the screw $h$ is partly turned, the pin is removed and the combination swings back to the

position shown in the drawing. In some presses hydraulic pressure with lever attachments is resorted to after the large screw has been tightened.

The MARIOLLE-PINGUET press (Fig. 217) is first tightened with the screw *B*, and when hand-power has reached its limit oil or glycerine is introduced into an end space acting as hydraulic press. The piston *A* is made to penetrate the liquid mass and exerts its pressure upon *B*. The power exerted is shown on a suitable pressure gauge. The mode gives a most satisfactory result. In the CIZEK monster press the closing is accomplished in very much the same way (Fig. 212). A large movable piece *l* is held in equilib-

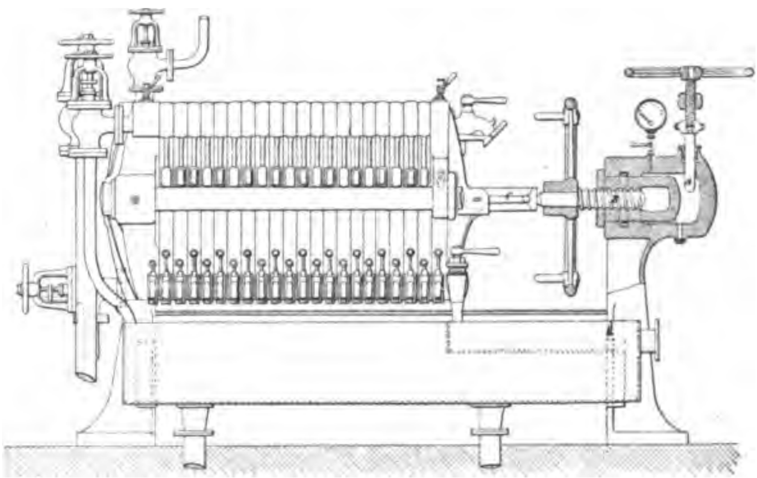

FIG. 217.—MARIOLLE-PINGUET Press, showing Device for Tightening Frames.

rium by counterpoises *e'*. Water under pressure is introduced through the pipe *b* into the compartment *A*, and the piston holding the tightening screw is forced against the frames of the filter press under considerable pressure. Experience is the only guide to determine within what limits the pressure may be exerted without breaking the frames or crushing the filtering cloths. The types of filter presses for carbonatated juice are very numerous, but only a few of them have been generally used.

**Collecting gutters.**—Outside of the filter presses and extending over their entire length are suitable gutters to collect the juice and the sweet water of scum washing. These gutters should be of sufficient capacity to hold a large quantity of the filtered juice

that may run from the presses in case of emergency, when for example the inlet valve of the next apparatus is shut without previous warning. This receiving gutter generally has several exit openings and an overflow attachment. One of these openings communicates with the second carbonatation tank and the other with the liming receptacle, and like communications are also made with the overflow. These orifices may be closed with valves, or better with wooden stoppers. Frequently the gutters are graduated on the inside to permit the estimation of the volume of sweet water obtained. The filter-press frames have several valve attachments which should be kept very clean. Should they be leaky complications may arise, and in the case of the water valve there is a possibility that water may dilute the carbonatated juice. The arrangement of the filter presses in the factory should be such as to make them accessible from all sides, thus permitting careful watching and leaving sufficient space for their emptying. Furthermore, this section of the building should be well ventilated to permit a free escape of the vapors thrown off during the unmounting and emptying of the frames.

**Filtering cloths.**—As a filtering medium tissues of various kinds are used, the selection of which has an important bearing upon the efficiency of the scum presses. In some cases preference is given to heavy cloths of good quality, in others a light, thin tissue is used. Generally for the first carbonatation presses a tissue of jute, a coarse hemp, seems to be preferred. It is inexpensive and withstands the action of alkaline juices.

In some factories preference seems to be given to linen cloths, while for the cloudy juices of first carbonatation coarse cloths are preferred. According to COLLIGNON,* the closeness of the fibre of a filtering cloth depends upon whether it is intended to filter juices from a monte jus or scum pump, the former demanding a tighter texture than the latter. On the other hand, for the filter presses of the second carbonatation the cloths should be of a finer texture and may be of cotton. Filtering cloths should be rather larger than appears necessary as they shrink under the influence of heat and the alkaline juices. Notwithstanding the fact that hemp cloths will shrink less than woollen ones they are always two or more centimeters wider and longer than the size of the frame demands. The cloths should be properly hemmed

* Bull. Ass., 9, 155, 1891.

so as not to ravel out during washing, even though this is somewhat difficult when the cloths have a central opening.

The life of a filtering cloth of this kind depends upon the degree of alkalinity and the temperature of the carbonatated juice being filtered. In beet-sugar factories where the methods of working during carbonatation are faulty the filter-press scums contain considerable free lime, which, at the temperature at which the presses are worked, acts upon the tissue of the filtering cloths and soon renders them worthless for the purpose intended. A like difficulty arises when through some mistake non-carbonatated juices are sent through the filter presses.

When the scums are poor and the cloths must be frequently cleaned preference is given to a tissue of average quality, not too light and able to resist the destructive effects of repeated washing. However, with beet juices that give the best scums there is decided economy in using a light tissue and allowing it to remain in the presses until worn out, that is from eight to fourteen days and sometimes much longer. That the filtering cloths should have a definite size so that they will not crease is self-evident.

**Ears of frames.**—The projecting ears of a filter-press frame are pressed firmly together by sliding between them strips of cloth prepared in advance from the same material as that used between the frames. Sometimes instead of these strips rubber rings are used which are readily handled, but they are more expensive and are worthless after one campaign.

**Working of a filter press.**—It is important to heat the presses before the juice circulates through them, otherwise it would be cooled, which, as previously pointed out, diminishes the facility of filtering, as cold or moderately warm juices do not filter as readily as do hot ones. The presses are treated by means of steam which enters by any of the canals and runs through the frames and disks. This heating should be continued only for a reasonable time, as otherwise the filtering cloths would be burned. After the presses have been properly warmed the steam valve is closed and the entrance valve for the juice is gradually opened. Malander says that the advantage of this mode is that particles of lime carbonate may be thus distributed upon the filtering cloths so that they cover the filtering surface without clogging the pores of the cloths.

When the valve of an empty press is open the juice runs off with considerable force through the discharge cocks. The larger

the deposit of scums upon the filtering cloths the more difficult will be the passage of the circulating juice and the slower will be the exit of the filtrate. After one or two hours, the press being entirely full, the juice running off is reduced to an insignificant stream.

The filtrate is not clear when it first runs from the presses, in fact it is very cloudy, and it is only after passing through a certain thickness of scum that it becomes perfectly clear. The rapid flow from the exit cock only lasts a few minutes, and during this period one may form some idea of the working of the press. When the volume of juice running off becomes comparatively small it is desirable to start another series of frames, otherwise the following phases of the manufacture would be somewhat retarded. There are generally two or three presses in full working activity depending upon the facilities for emptying, besides which there are several presses undergoing the process of scum washing or emptying.

To allow a press to continue working too long would cause an ultimate waste of time, while, on the other hand, a press that is not entirely filled will not give satisfactory results. The soft scums it contains if not well scraped off would cause leakage, etc. As a good scum cake, or at least a solid texture, greatly facilitates the work of washing precaution should be taken to fill the various compartments completely, even when the exit flow is slow. The difficulty is not overcome by emptying the press when the first evidences of trouble are shown by the slow-exit flow, because the time lost in removing the soft scums is more serious than the inconvenience they cause, such as the clogging of the filtering tissue, leakage of the press, etc. It is better to wait until the compartment of the filter press is entirely filled and yields dry scums.

**The importance of scum washing** is evident when one considers that the waste product has no industrial value, and that it contains a certain amount of sugar. The sugar percentage of scums which have not been washed varies with that of the carbonatated juice and the amount of insoluble saccharate eventually remaining in the residuum. Upon general principles, it may be said that beet scums are made up of 40 parts of solid substances and 60 parts of juice. If the latter contains 10 to 12 per cent of sugar the saccharine percentage of the scums is about 6 to 7 per cent.

The scum washing should be conducted in such a manner as to

obtain very concentrated sweet waters, obtaining at the same time a satisfactory elimination of sugar from the residuum. This result may be realized only by driving the juice from the scums in some suitable way during its passage through the presses.

The essential condition for successful scum washing in the presses is that the cakes be uniform in texture and thickness in all the frames of the same press, and that the filtering cloths be uniformly porous. If the scum cake is thinner or softer at one place than it is at another, as for example, in the upper part of badly filled presses, more water passes at that portion than where the thickness is greater, and those portions are entirely exhausted of their sugar while the others still retain an abnormal amount. This difficulty is more apparent when there is an increased pressure in the apparatus. However, the irregular penetration of the scum cakes can never be entirely overcome, as owing to the construction of the presses even the best and most regular scum cakes always have some inequalities. In the compartment presses the soft portions are to be found along the exterior sides where the cakes are thinnest and where the filtering cloths are held together. In the presses with frames they are found along the iron frame as the adhesion of the scum to the iron is less than that uniting the particles of the scum cake proper. Too great a compactness of the scum cake is also objectionable for its satisfactory washing, as the operation then is extremely slow throughout the entire mass and the water pressure must be increased.

**Different methods of washing.**—The washing is generally conducted in the filter presses, but in some beet-sugar factories the scums are removed from the presses before they are exhausted of their sugar, and are then mixed with water and again filtered. By this method of working a diluted sweet water is obtained with the same loss of sugar in the scums as that occasioned by washing in the presses proper. The last mode has the important advantage that the filter presses used may be of very simple construction. The scums are projected against the sides of cylinder *B* (Fig. 218), which revolves in the receptacle *D*. When the scums are sufficiently saturated with water they are drawn through *E* to the scum pump, from which they are forced into a special filter press. This method requires a special plant and its working is dirty in the extreme.

The washing of the scums in the presses may be done in two

ways. The water may enter by special passages on one side of the scum cake and passing through make its escape on the other side; or it may follow the same direction as the carbonatated juice—that is, enter through the centre of the scum cake and pass through the halves, escaping on both sides. This method is

FIG. 218.—Scum Mixer.

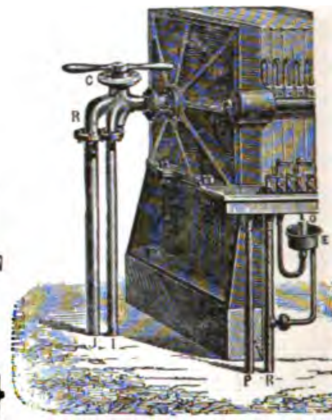

FIG. 219.—GALLOIS Washer.

especially applicable to presses in which the juice enters at the centre of the disk. GALLOIS (Fig. 219) uses with this arrangement a three-way cock attached to the filter presses, in which circulates the water to be used for washing and the cloudy juice from the carbonatation tanks. This cock allows the introduction of two liquids into the filter presses between the two halves of each scum cake, and, furthermore, the amount of each liquid admitted may be regulated as desired, or either one may be cut off entirely.

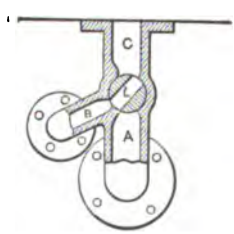


FIG. 220.—Detail of GALLOIS Three-way Cock.

The advantage of the GALLOIS mode of washing is that it may be applied to any filter press. When (Fig. 220) the scums enter at *A* the outer pointer shows that *L* is in the normal direction *A–C*. Scums alone are allowed to pass, and after a reasonable interval the frames are filled with them. When the juice running from the exit cock diminishes very much, the key places the cock in the position shown in the drawing so as to allow the boiling water to enter through *B* with the scums,

resulting in a mixture of water and scums, the density being necessarily lowered. After a short interval water alone is allowed to circulate by cutting off $A$, and after a few minutes the hydrometer placed at the bottom of the press shows that it is useless to continue the washing. The advantage of using boiling water with this process is said to be that the sweet water contains less organic substances than if cold is used.

With filter presses for the exhaustion of the scum cake through its entire thickness this method of working possesses special features. The cloudy-juice valve is closed, and when the filtrate no longer runs off all the exit cocks of the frames into which water enters are closed. In order to distinguish them readily from the other cocks the handles of the exit cocks are placed higher. Water is then run into these frames, and after a given volume has circulated the entrance valve is closed and all exit cocks are opened. Of course this cannot be done unless the trough receiving the water has a special pipe for its removal. As the water of these frames does not contain sugar there is no advantage in using it during the process of sugar extraction. Certain filter presses have special canalizations passing through additional ears of the frames and communicating with each of the water frames, and a pipe attached to this passage carries off the water to the exhaustion tank.

The selection of the best mode of scum washing, either through the passages of the press and the scum cake taken as a whole, or through the juice passages and half of the scum cake, depends entirely upon local conditions. CLAASSEN * says that the latter method has the advantage of consuming much less time. As a general thing it is preferable with well-arranged presses to do the washing in the canal passages, as the scums are thereby placed under the same conditions, and are more satisfactorily freed of their sugar, while the sweet water is diluted less.

**Quality of the water used for washing.**—The wash water should be as pure as possible so as to thoroughly exhaust the scums of their sugar and not clog the filtering cloth. Preference is generally given to water of condensation and that which contains neither ammonia nor fatty substances; such, for example, as the water from the first compartment of a multiple effect, or that from the calorizators or reheaters.

* Z., 48, 1, 1898.

Under no circumstances should well water be used that may be considered hard, as in contact with the juices containing lime this would precipitate and clog the passages, not only of the press proper but of the sieve, and the filtering cloths would soon become harder. A lime deposit may also occur when using condensed warm water from the boilers, especially if they contain carbonate of ammonia instead of ammonia. When the juice has been over-carbonatated during the second carbonatation this difficulty is always to be dreaded.

**Temperature of the water.**—The question whether it is desirable to use hot or cold water for the washing has not yet been entirely settled. However, it is not probable that if pure water is used its temperature can have any great influence upon the purity of the sweet water coming from the presses. In most beet-sugar factories, there is available a considerable volume of pure, hot water, and it is more practical to use it than to attempt its cooling. The only advantage of cold water is that the scum is cooled and the workmen have not to contend with warm vapors while emptying the presses.

**Pressure of water.**—Opinions differ in regard to the most desirable pressure at which to wash out the scums. Many years since WALKHOFF called attention to the tendency to push the pressure to an exaggerated limit, he held that one-half an atmosphere is amply sufficient.*

It is to be noted that an excessive pressure is not compatible with satisfactory scum washing, while, on the other hand, at a very low pressure the sugar exhaustion is satisfactory, but the number of presses must be increased. Many experts recommend that the pressure be regulated to suit each special case, and that when the scum pump is working at low pressure the exhaust pump be operated at a slightly higher pressure. The rule given may be correct, but it seems more rational to determine the pressure of the exhaust pump so that a determined volume of sweet water may be obtained from the washing in a given time. To this end the pressure of the exhaust pump should be regulated according to the nature of the scums and the thickness of the resulting scum cakes, keeping, however, within a reasonable maximum limit so that the very variable consistence of the scum cake may not exert an excessive influence. A pressure of 2 atmospheres

* Z., 16, 638, 1866.

may be considered a good limit if it is desired to obtain a satisfactory washing with very little water. Every increase of pressure results in an increased volume and a dilution of the sweet water running from the presses without a corresponding decrease in the percentage of sugar remaining in the scum residuum.

**Scum-washing pumps.**—A special tank placed at a certain elevation sends the water under pressure to the scum-washing pump. A float upon the surface of the water will open the hot-water cock as the occasion may demand. The piston of these scum-washing pumps generally has a metallic packing. Upon the pipe connecting with the filter presses is a pressure gauge and a safety valve, regulated to meet the requirements of the work to be done. In case the water is unable to pass through the scums it escapes through this valve and returns to the pressure tank.

**Conclusions respecting scum washing.**—Scum washing should last for about 20 or 30 minutes for superior scums; under such circumstances about 100 parts of sweet water for 100 parts of scum are obtained. Upon general principles, it may be said that the degree of exhaustion depends upon the time given to the operation. If the pressure is increased, which it should be when washing poor scums, the volume of sweet water increases in a very considerable measure, and the time needed for the water to penetrate the mass decreases in the same proportion. However, in most cases it is impossible to obtain an exhaustion corresponding to 1 per cent. In most German factories 1 to 2 per cent is considered satisfactory.

**Use of gas and other substances.**—As the scums had to be exhausted of their sugar by driving out the combined juice it was argued from the very beginning that some substitute should be found for water which always dilutes the juices. Gas was suggested, ROBERT * proposing carbonic acid, and then STENZEL suggested compressed air.

By the LAHN † method one violent stroke forces compressed air into the filter presses; in this way the scum cakes are very solid and homogeneous. The deposits take the shape of the frames which are purposely made slightly conical. The liquid can reach the surface of the frame and run off without difficulty. This operation is effected before washing.

With the same idea in view steam was used, following the water washing. By this process there is a saving in the volume of water

* Z., **14**, 419, 1834.

† N. Z., **42**, 260, 1899.

used, but the filtering cloths suffer. Complete exhaustion of scums by the use of steam should not be considered, as STAMMER'S* experiments showed that steam in the long run gives very poor results.

**Limit of exhaustion.**—Upon general principles, every possible effort should be made to remove all traces of sugar retained by the scums. This is hardly realizable in practice on account of the enormous volume of water that would be needed, which, when subsequently added to the juice, would necessitate the expenditure of more fuel for its evaporation, and this would hardly be compensated for by the additional sugar obtained. It was long since noticed that the sweet water running from the filter presses becomes very poor through excessive scum washing.

Water will frequently redissolve some of the non-sugar of the scums, and for this reason the last portion of the sweet-water filtrate, in which considerable water has mixed with the juice drawn off, is of a lower purity than that running from the presses during the early period of their working. This purity, however, remains sufficiently high to give a *massecuite* which will crystallize with comparative ease. There is very little objection to submitting the scums to considerable washing, provided, however, that there is a sufficient number of presses for the work, and this is not followed by excessive dilution.

SACHS and DEBARBIERI † have determined the purity of the sweet water running from filter presses during washing. The experiments were conducted in a filter press containing 400 kilos of scums and gave the following results:

QUALITY OF JUICE FROM FILTER PRESSES DURING WASHING.

| Number of Liters Withdrawn. | Brix. | Sugar. | Purity. |
|---|---|---|---|
| | | Per Cent. | |
| 240 | 4.32 | 3.39 | 78.4 |
| 280 | 2.70 | 1.99 | 73.7 |
| 320 | 1.15 | 0.68 | 59.6 |
| 360 | 0.72 | 0.38 | 52.7 |
| 400 | 0.68 | 0.21 | 30.8 |

As the analysis of diluted juices can never be accomplished with the desired accuracy too much stress must not be placed

* Z., 15, 287. 1865. † Bull. Ass., 3, 82, 1885.

on these data. HERZFELD * has concentrated the sweet water until it had the consistency of *massecuite* and obtained very different results, which demonstrated that even when the sweet waters are excessively diluted they still contain crystallizable sugar.

VERSCHAFFEL † treated the sweet water having a purity of 53 exactly as if it were the regular juice in the factory, that is to say he added lime and carbonatated it twice and it ultimately had a purity of 90.

**Usage of sweet water.**—Any use of the sweet waters from filter presses other than as a substitute for water during the phases of beet-sugar extraction when water is needed cannot be considered. The principal usage is for diluting milk of lime. It was suggested by ZWERGEL and LION ‡ that such factories as use dry lime should utilize these sweet waters in the diffusion battery, in which case they would not necessarily dilute the juices. The MARIOLLE-PINGUET (Fig. 221) process, which for many years was adopted in some factories, was based upon very much the same principles. The work is conducted as follows: The diluted juices from the filter presses *a* are collected in the trough *b*, in which they are measured, and from which by a pipe they enter the carbonatation tank *d*, and then pass through the pipe *g*, and are pumped by *h* into the diffusors of the battery. In the MARIOLLE-PINGUET method the volume of carbonatated sweet water is accurately measured before being introduced into the diffusion battery. It is claimed that the daily capacity of a given sugar plant may be increased in this way, for the reason that the carbonatation tanks and multiple effect will be relieved of work to a degree corresponding to the amount of carbonatated sweet water introduced into the battery. The method has lately been taken up by GEESE § and slightly changed. In this case the sweet water from the filter presses is introduced into the fourth or fifth diffusor from the end of the battery. It is stated that this sweet water could not be introduced into the last diffusor of the battery, as there would be danger of the cossettes taking up the sugar by osmosis, and its introduction into the first diffusors would retard the entire working of the battery. The quantity of juice drawn off for a given exhaustion and the purity obtained is about the same as it is by other modes and under normal conditions.

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* Z., **38**. 1231, 1888.

† La. S. B., **25**, 505, 1897.

‡ Oe.-U. Z., **3**, 204, 1874.

§ C., **10**, 1090, 1904.

In some methods of handling filter presses the most diluted sweet water from one press is run into another press during the first stages of scum washing. While certain advantages are evidently gained thereby the general practical application of

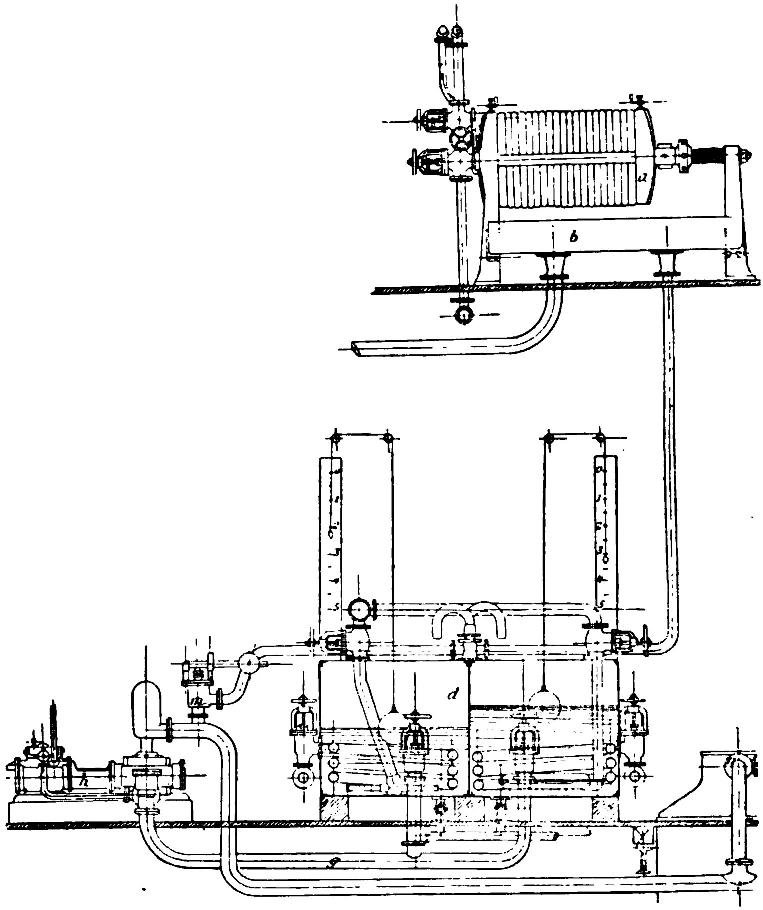


FIG. 221.—Arrangement of MARIOLLE-PINGUET for Sweet-water Utilization.

the plan offers objectionable features, which explains why it has not been more generally adopted. As the total volume of the sweet water and the water that passes through the scums is much greater than with standard methods of washing scums with pure water the time of working is necessarily longer. This method is as follows: *

* S. B., Jan. 1902.

The sweet water from filter presses is made up of four parts containing a varied amount of sugar and foreign substances. The first part is sent to the receptacle for mixing lime and water. The second part is used for washing the residuum scums in new presses, etc. The scums by this methodical washing are entirely freed from their sugar, and the impurities of the juice are almost entirely eliminated after defecation and carbonatation. The advantage claimed for this sweet water utilization is that a minimum volume of water is used, resulting in an economy of fuel for subsequent evaporation.

STEFFEN * is in favor of excessive exhaustion of the carbonatation scums in the filter presses. These sweet waters are cooled to about 30° and are then exhausted by the separation method. The precipitated saccharate is collected in a special filter press, and if it is very pure it is either added to diffusion or other juices.

In beet-sugar factories where milk of lime is used for defecation the most diluted sweet water should be kept separate, as it may be subsequently used in lime slaking, for which purpose 5 to 6 parts water are needed for 1 part of lime. As 1 part of lime gives about 3.5 to 4 parts scum it is self-evident that for defecation with milk of lime there need be no apprehension of excessive dilution of the sweet water running from the scum presses. There is needed in volume 150 per cent of the weight of the scums for lime slaking. On the other hand, any dilution of the sweet water should be avoided when dry lime is used, as it then is of no special use other than that of being added to the juices during carbonatation, and the advantages of defecation with quicklime would then become considerably lessened when considered from a fuel standpoint.

**Perturbations in filter presses.**—It is well known that a slow filtration in the scum presses or, in other words, the non-filtrability of the juices and softness of the scums, may be attributed to the kind of beets used and to the process employed in the factory.

Attention has already been called to the fact that when certain beets are employed for sugar extraction the working of the diffusion battery has an important influence upon the nature of the resulting scums, and if inferior oils have been used as froth arrestors during carbonatation, they will tend ultimately to clog the filtering cloths. When the quality of the beets is responsible for the faulty

* Oe.-U. Z., 32, 70, 1903.

exit flow from the scum presses the difficulty can be overcome by making some change in the handling of the diffusion battery. According to CLAASSEN, "increasing the amount of lime used during defecation has rarely the desired effect," even aside from the fact that most factories are unable, because of the special arrangements of the plants, to control the quantity of residuary scums obtained, the volume of which is considerably greater than that given by former methods of working. Very little success is obtained by boiling the juices, as is frequently recommended, because there is then greater difficulty in emptying the scum presses than if they are heated to 80° or 90° C. as by standard methods, and, furthermore, there is no improvement of the resulting scums. Even an increased alkalinity of the juice seems to be of no avail, and indeed all expedients appear to be useless, and the best and most desirable solution is that of continually renewing the filter cloths. The troubles contended with in the scum presses occur mainly at the beginning of the sugar campaign when the beets are not yet matured and new and inexperienced workmen have charge of the presses. These difficulties become less as the campaign advances.

CLAASSEN'S arguments are in many respects in direct contradiction to the experience of many of the leading experts who claim that they have obtained with these expedients at least as good results if not better than without them. When the juices contain too little lime, more should be added to the carbonatating tank just before it is emptied and the carbonatation continued for a short time. While lime is a very important factor in this filtration it does not always overcome the difficulty. Efforts, however, should be made to ameliorate the situation if only to a moderate degree, and the lime mode appears to be the most efficacious.

It is evident that, owing to the transformations occurring during carbonatation, juices which have been poorly carbonatated, either excessively or not sufficiently, will cause difficulties during their passage through the filter press. It is consequently necessary to give the greatest possible care to all the details of carbonatation, especially when the scums are of very poor quality. The exit flow from the presses may be very unsatisfactory even with juices that have been properly carbonatated, for these may be combined with poorly carbonatated juices by a leakage from the emptying valve of the carbonatating tank, or when the frothing is excessive,

producing an abnormal pressure which forces the juice from one tank into another.

Poor scums may be due to an excessive alkalinity of the filtrate, some juices having alkalinity slightly higher than that possessed after the operation of carbonatation is complete. A slight increase of alkalinity is nearly always produced in the scum presses, as the scums unite with a certain amount of quicklime or saccharate of lime which, little by little, dissolves throughout the entire thickness of the scum cake. This increase of alkalinity generally corresponds to 0.01 per cent of lime. SACHS's * experiments tend to show that magnesia in the limestone used in the kiln is responsible for poor filtration in filter presses.

Upon general principles it may be said that when the presses are faulty in their working especial attention should be given to the liming and carbonatation. When it is noticed that the flow from the filter presses is slow and cloudy the tendency is to increase the pressure at which the cloudy juice is made to circulate, but generally this helps very little and frequently causes leakages. No especial complication results from introducing cloudy juices into the second carbonatation tanks unless it is carried to an excess. When the presses are taken apart some cloudy juice always flows off which is either sent to the defecation tank or mixed with the filtrate.

If the filtering cloths are worn and do not do their work, giving a cloudy filtrate, which for any reason cannot be sent back to pass again through one of the phases of liming, it is simply allowed to flow off with the clear filtrate. If several cloths burst the exit cocks should be closed, as otherwise the second carbonatation presses would not work satisfactorily. Under all circumstances a faulty cloth, or one that has burst, should be renewed when the press is taken apart. Many of the difficulties arising in case of a break in the filtering cloths are overcome by the use of the WEHRSPANN † double gutter into which all the cloudy juice running from the press is emptied through an S-shaped tube to be again emptied into the first carbonatating tank. By this arrangement the filtrate remains pure and all the other cloths can remain in the press until they are worn out.

It frequently happens that the circulation in the presses is so defective that all the pores of the cloths become clogged with scum.

* Z., **39**, 667, 1889. † D. Z. I., **25**, 1770, 1900

These deposits may be partly removed by scraping, but the better plan is to renew the cloths entirely. To overcome this difficulty the cloths are often washed on the frames with a brush and water, or by means of steam, without unmounting. Experience appears to show that if the well limed and carbonatated juices continue to circulate through the presses most of the clogging will disappear after several fillings without further trouble.

**Scum cakes** are the result of the deposits between the filtering cloths in the presses and are gradually formed. The heavy particles such as sand, are deposited in the lower division of the section as long as the scums remain soft, this portion between the cloths filling more rapidly than the upper part. But, as a general rule, when the pumping pressure is not too low the scum is deposited in regular layers owing to the continuous passage of the juice through the cloths. This is made evident by examining the variously colored particles shown throughout the thickness of the scum cake. Each carbonatation tank gives scums of a different composition and color, which explains why the series of layers of which the scum cake consists vary in color from yellow to a very light blue.

**Aspect of the scums.**—All facts considered there is no better way to judge whether the press has been working under normal conditions than by the exterior aspect of the scums. When the juice has been properly limed the scums have a light, yellowish-gray color. When the amount of lime used is slightly in excess of the normal the color becomes very much lighter and the texture finally becomes chalk-like. If the alkalinity is too low the scums are dark in color and have a greenish aspect. If part of the scum deposit is broken open there will be noticed a series of layers and colors each of which denotes some change in the alkalinity. On the other hand, when too little lime has been used the scums are soft and pasty and dark in color.

**Composition of scums.**—According to ANDRLIK the chemical composition of filter-press scums in beet-sugar factories varies very considerably. The analyses given (p. 437) are of twelve samples that filtered well and seven that were of difficult filtration.

The main difference shown between the scums from a satisfactory and a poor filtration is the proportion between the organic substances and the lime. The microscopical examination * of these two scums reveals nothing. KOLLREPP † has also made

* B. Z., **23**, 163, 1898. † Z., **38**, 354, 1888.

a thorough examination of them, and the conclusions drawn did not differ from those of ANDRLIK.* It is important to note that this chemist also found in the scums isocholesterine and acid tricarballylique, and, furthermore, an average of 0.7 per cent of citric acid and about 2 per cent oxalic acid.

ANALYSES OF FILTER-PRESS SCUMS.
(Dry substance.)

| Constituents. | Filtration Satisfactory. | | Filtration Poor. | |
|---|---|---|---|---|
| | Minimum. | Maximum. | Minimum. | Maximum. |
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Silica and insoluble substances.... | 0.53 | 2.99 | 0.67 | 3.13 |
| Ferric oxide and alumina........ | 0.84 | 4.23 | 0.45 | 3.86 |
| Calcic oxide.................... | 41.31 | 47.13 | 39.52 | 46.79 |
| Hydroxide of lime............. | 0.14 | 2.49 | 0.00 | 1.14 |
| Magnesia...................... | 1.71 | 5.13 | 0.53 | 2.78 |
| Carbonic acid.................. | 26.11 | 33.80 | 26.11 | 32.85 |
| Phosphoric acid............... | 1.09 | 2.06 | 0.92 | 3.03 |
| Sulphuric acid................. | 0.53 | 4.10 | 0.50 | 3.68 |
| Fatty substances.............. | 0.05 | 1.29 | 0.65 | 3.49 |
| Nitrogen...................... | 0.22 | 0.36 | 0.14 | 0.44 |
| Pentoses...................... | 0.17 | 1.11 | 0.12 | 0.80 |
| Undetermined.................. | 6.64 | 14.98 | 8.17 | 18.32 |

From what has been said it is evident that from the chemical composition of the scums no important conclusions can be drawn as to the working of a filter press, but the analysis reveals very plainly the value of the residuum to agriculture.

**Use of scums in agriculture.**—As the scums contain considerable quantities of phosphoric acid, nitrogen, potash, and calcium carbonate, great benefits can be derived from their utilization as a fertilizer. Those familiar with the requisites for plant foods know the advantages to be derived from the use of lime upon soils that are to be cultivated in beets. Even soils very rich in lime are improved by the addition of filter-press scums, especially when the lime is in the form of a silicate. According to BORGNINO and COLOMBO,† some soils may be benefited by the addition of 260,000 kilos per hectare.

CLAASSEN says that when only a small amount of lime has been used for defecation the resulting scums make the most desirable fertilizer, as the percentage of phosphoric acid and nitro-

* B. Z., **22**, 28, 1897; B. Z., **24**, 645, 1900; B. Z., **25**, 139, 1900.

† Delle Schiume di Defecazione, Bologna, p. 47, 1902.

gen is then higher than it is after excessive liming. Many European farmers have recently begun to realize the importance of scum as a fertilizer, although a prejudice existed against it for a long period of years. It was, for example, maintained that the use of scum was responsible for certain beet ravages, such as those of the nematodes. But such theories have been shown to be absurd, as no living organism could resist the destructive action of lime. The difficulty of spreading it upon the surface of soils is also in a measure responsible for its being little used for agricultural purposes. The drying of the product seems to have met with some success.

**Scum drying.**—The PASSBURG dryer, which has given satisfactory results with filter-press scums, consists of a double cylinder heated by steam, in the interior of which revolves another cylinder with outside projecting surfaces which form depressions on the surface of the scums, through which the steam may circulate on its way to the condensor. The apparatus works in vacuo. The substance being treated is introduced into the dryer through a funnel, in the interior of which revolves a spiral that forces the pasty mass into a pump, from which the scums are pressed into the cylinder. Although in some cases the manufacturers of fertilizers use this product to increase volume, etc., the practice is evidently a bad one, as the scums contain high percentages of carbonate of lime which would render insoluble the previously soluble phosphate of the fertilizer.

**Emptying of filter presses.**—The mode generally adopted is to empty a filter press into the hopper *S* (Fig. 222) which is subsequently emptied into the car *W*. As the bottom of the hopper is frequently very difficult to open a rock working on the cogs of *H* is used. When the filter presses are in operation the hopper is covered with sheet iron upon the surface of which the juice runs off into the gutter. This sheet iron remains in position until two or three frames have been separated.

Sometimes the plan of the factory does not allow of using the hopper combination and the arrangement is then as shown in Fig. 223. The contents of the presses are emptied into specially constructed flat cars *K*, which circulate under the presses. When the juice has been filtered under normal conditions the scum is readily emptied from the frames, a slight shock making it fall into the hopper beneath. Should it adhere it is separated with wooden scrapers. It is advisable to grease the bar upon which

the rollers or supports of the filter-press frames move. Generally at least two men are needed for the emptying of a filter press, and for a 500-ton beet-sugar plant four or six men.

The residuary scums are carried in cars outside of the factory

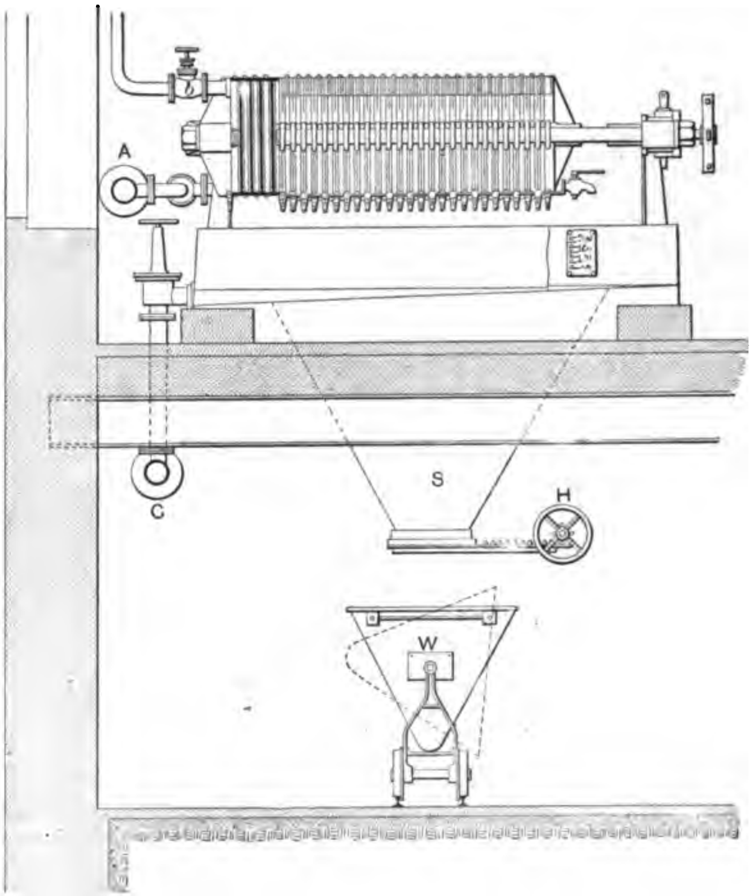


FIG. 222.—Arrangement for Filter-press Emptying.

and emptied upon a pile with other waste. In some cases the scums fall into a spiral carrier, or into a scum mixer placed beneath the presses, in which, after the addition of a small quantity of water, they are reduced to a pasty mass and flushed out into decanting tanks with the residuary water of the factory, or carried by suitable pumps to a considerable distance where they will do no harm. Another plan suggested is to discharge the contents

of the presses directly upon a moving rubber belt, from which, after reaching the end of the journey, they fall directly into the wagons. In case the scums are sticky a special scraper removes the adhering residuum from the belt.

The track from which the scums are emptied should be very high so that the residuum may fall by gravity. Handling the product with a fork is too difficult even to attempt. When iron cars of the DECAUVILLE type are used it is found desirable, in order to facilitate their subsequent emptying, to sprinkle the sides with

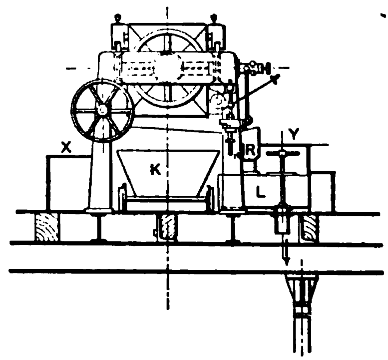


FIG. 223.—Flat Car Emptying from Upper Level.

water before filling them. An economical method for disposing of these residuums at some distance from the factory consists in using cable cars running to the spot where the product is to be deposited. At this place the car is emptied automatically by the contact of the bottom with an obstruction. The car is returned to its destination by simply reversing the cable, and before reaching the factory the bottom comes in contact with an inclined plane and the emptying door is closed. Handling the residuum scums is a very dirty operation, and if not done with care the entire yard of the factory will be made unclean by them.

**Renewing of filter cloths.**—Upon general principles it may be said that the filtering cloths should be renewed every eight days. In some factories they are made to last longer, but such a practice is evidently a mistake, for after a time the cloths harden and are no longer porous. The use of ammoniacal and calcareous water soon destroys a filtering cloth. One should not hesitate to replace cloths when their renewal is thought necessary, as the

work of washing and the time necessary for the removal of the old ones and placing the new ones in position is more than compensated for by the improved filtration. If the cloths are simply dirty, only the upper one need be changed. Should it happen that a sufficient number of cloths for the renewal of all is not available the worst ones are kept underneath and the new ones put on top.

In some factories the renewing of the filtering cloths is frequently neglected until a cloudy filtrate appears, when the press is entirely unmounted and all the cloths renewed. In some cases a double series of cloths is used, those that have been washed being placed in position first with the new ones on top. CLAASSEN says that when jute cloths are employed it is unnecessary to dip them in water before placing them in position as is customary with the standard cloths. Many advantages are said to be derived from this mode. In some factories, however, the middle of the cloth where it comes in contact with the top of the frame is dipped, as it is then much easier to stretch into position.

**Filter-cloth washing.**—Special machines are used to wash the cloths; excellent results have been obtained with a revolving drum divided into several compartments through which hot water circulates continuously; in the compartments only partly filled with water the cloths are thrown from one side to the other. Sometimes this washing is done in barrels revolving around an oblique axis, the cloths being tossed from one side to the other after each revolution. The washing should not last too long. The corners of the cloths are most worn, and care should be taken in unmounting the frames to keep the cloths in the best possible condition.

Some recommend diluted hydrochloric acid for washing the cloths. Without doubt old cloths may thus be freed of their lime, but as the acid frequently contains sulphuric acid they would soon be destroyed. Filter-press cloths after washing may be dried in some warm part of the factory, near the crystallizing tanks for example, and if possible should be ironed, as this greatly facilitates placing them in position on the frames. It is of course a great mistake to pile damp cloths on top of one another as they would soon rot.

It is not generally necessary to clean the sieve or the passages of the filter press during the campaign, but after its close this should not be neglected. All passages for the juice and water and those connecting with the emptying valves and cocks are more or less clogged with calcic deposits, and if these are not

readily removed acidulated water should be forced through the canal passages of the pump, followed by a thorough flushing with water to remove all traces of acid. In order to obviate any possibility of rust the perforated disks should be varnished as soon as dry. If one fears that the acid may attack the plates they should be cleaned with small cog-wheels, the diameters of which are the same as the distance between the perforations or openings of the disks. In many beet-sugar factories it is customary after the campaign has ended to force hot acidulated water to circulate through the presses. Such modes should be operated with extreme care, so that the pump, piping, and other parts of the press may not be damaged.

## CHAPTER V.

### SECOND CARBONATATION.

**Importance of second carbonatation.**—The carbonatated juice leaving the filter presses of the first carbonatation generally has a high alkalinity, and the excess of lime should be eliminated during the following operations. Second carbonatation eliminates at the same time a certain amount of other foreign substance. This operation is conducted with or without the addition of lime. If only one saturation follows the first, the treatment consists in a free use of carbonic acid, either alone or in combination with sulphurous acid. In case two saturations follow the first the second is effected with carbonic acid alone, and the third with carbonic followed with sulphurous acid, or the third may consist in sulphuring alone, no carbonic acid being used.

For years there has been considerable discussion as to the relative advantages of two or three saturations. It cannot be denied that with three saturations the alkalinity may be more carefully regulated and that one may thus more readily obviate the objectionable precipitates, which are to be feared in excessive saturation. Three saturations increase the difficulties in general sugar extraction, and, furthermore, call for additional supervision. As a consequence most factories limit the work of this epuration to two saturations, known as first and second carbonatation.

**Triple carbonatation.**—According to WEISBERG, some factories have pushed this idea of saturation so as to make as many as six carbonatations. To MISIAGIEWICZ * is due the credit of having first suggested three successive carbonatations, a plan which has met with much favor in Bohemia. Satisfactory results may also be obtained by the KARLIK † process by which it is possible to separate 4.25 parts of non-sugar for 100 parts of sugar. The greater part is separated during the first carbonatation and an

* Z., **24**, 423, 1874.

† B. Z., **25**, 195, 1900.

appreciable amount during the second one. During the third carbonatation very little organic substance is separated, the main object then being to eliminate the excess of lime in the solution. The process claims to be a fractional precipitation of foreign substances at different degrees of alkalinity. About 45 per cent of the nitric elements but only 17 per cent of the albuminoids is eliminated.*

The question as to the advantages to be derived from submitting saccharine juices to three carbonatations continues to be discussed. Laboratory experiments have recently been made by several well-known chemists, and they declare that no difference is noticeable in the chemical composition of juices that have been epurated by three rather than by two carbonic acid treatments. The *massecuite* from a triple carbonatation juice was a fraction clearer. Undoubtedly the epuration may be satisfactorily accomplished by two carbonatations, provided the accepted rules for conducting the operation are followed.

Furthermore, triple carbonatation offers many disadvantages, among which may be mentioned cooling of the juices, increased labor and cost of plant, for which the advantage offered by the process does not compensate.

It is to be noted that even in Bohemia the leading experts † are pointing out the disadvantages of three carbonatations, and without doubt it is only a question of time when it will become obsolete. Fifteen years ago WEISBERG ‡ insisted that this method offered no advantages provided the second carbonatation had been properly conducted. Evidently, on the other hand, if the first carbonatation has been in a measure neglected the harm done may be considerably lessened by a second carbonatation. However, it is to be noted that this is not a desirable way to work, as the results would never be equal to the expectations.

**Single carbonatation.**—Just as there are many advocates for doing away with the third carbonatation so there are others who recommend the suppression of the second saturation. Single carbonatation combined with sulphuring is said to give all the satisfactory results which it is possible to obtain by double carbonatation. Experiments apparently show that filtering after first carbonatation may be done away with when the sulphurous treatment is employed. This method of working simplifies the

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* S. B., May 1901. † B. Z., 25, 1901. ‡ La. S. B., 15, 348, 1887.

machinery of a beet-sugar factory very much, and, furthermore, it is made more economical.

According to AULARD * the natural purity of the beet juices renders a second carbonatation absolutely useless during at least two months out of the three that the beet-sugar campaign lasts. At the beginning of the factory work, when the beets sliced are not entirely matured, the second carbonatation is as essential as it is towards the end of the campaign when changes due to storage, and possibly freezing of the beets, must be considered. At other periods only a single carbonatation is necessary provided the lime is allowed to act upon the juice when cold and the temperature is gradually increased from 70° to 75° C. before the operation begins. However, it is doubtful whether the evaporation of the strongly alkaline juices of first carbonatation can be accomplished under these conditions without giving rise to numerous complications, such as lime deposits upon the tubes, etc. If the alkalinity were lowered considerably during first carbonatation there would be difficulties afterward in handling the magnesia salts contained in the juice.

**The addition of lime.**—The leading authorities do not agree as to the utility of adding lime to the filtered carbonatated juice of the first epuration. According to WOLF † this addition is not necessary, and in fact there are in Germany numerous factories where it is not done, but it is then generally customary to keep the juices of first carbonatation at a high alkalinity. On the other hand, the majority of the factories maintain that while this addition of lime is not indispensable it is useful.

It is the general opinion ‡ that the epurating action is greatest when lime is added twice, carbonatation following each addition. The epuration is in direct ratio to the quantity of lime used and the dilution of the juice. Precaution should be taken not to go beyond the limits considered financially profitable. The quantity of lime added varies greatly, oscillating between 0.25 and 1 per cent. In the KARLIK triple carbonatation 0.4 per cent of lime is added before the second carbonatation, and during the third carbonatation there is no further addition. It is to be noted that if the quantity of lime used during second carbonatation is too small the juices have a tendency to froth in the multiple effect.

Generally it is the custom to add to juices before the second carbonatation an additional 0.25 per cent of lime in the form of

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* 5e Congres, **60**, 1903. † Oe.-U. Z., **21**, 1892. ‡ D. Z. I., **24**, 366, 1899.

milk of lime. This serves no appreciable purpose, because the lime remaining in solution in the first carbonatation juice is amply sufficient to continue the transformation of the non-sugar. With dry defecation for first carbonatation a second addition of lime is superfluous, and it is then no longer necessary to prepare a milk of lime. The direct addition of dry lime to hot juices will increase the formation of the insoluble calcic saccharate, and, therefore, is not desirable.

Lime is added to beet juice in various ways. The addition of milk of lime during first carbonatation has been previously described. If two carbonatations are practised and dry lime is used the milk of lime is prepared exclusively for the second carbonatation, but usually the dry lime is simply added to the juice. One method consists of adding the lime to the filtrate from the first carbonatation and mixing it thoroughly in a special appliance, while another method, but one which cannot be recommended as there remains only a limited time for mixing, consists in adding the lime to the juice in the carbonatating tank. By the SEIDER * method the lime used is of an exceptional purity in order to precipitate the magnesia which is in the first carbonatation juices, the quantity used depending upon the care given to this operation. The organic magnesia salts are transformed in the presence of an excess of lime into magnesia and lime salts which precipitate and thus avert all possibility of the formation of crystals by a combination with magnesia in the after-product, which are said to prevent, or at least to render considerably more difficult, the swing out in centrifugals.

**Reheating of juices.**—The juice or filtrate running from the presses is received in the second carbonatation tank. As they have cooled somewhat in the presses and in the outside gutter collector they should first of all be reheated, using steam or vapors from the evaporating appliances for the purpose. This reheating should continue until the juice boils, and after the first filtration the temperature should always be kept at about 100° C., which is not only favorable for the calcic action upon the non-sugar, but is necessary to prevent the lime from being again dissolved as a bicarbonate during the second or third carbonatation. When lime is added during the second carbonatation, the reheating of the juice should be effected before the calcic treatment in order that the juice already rich in lime may not reach the boiling point

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* Z., 49, 934, 1899.

as juice saturated at 70° or 80° C. with lime allow perceptible quantities of an insoluble saccharate of lime to precipitate if heated up to 100° C.

**Operation of second carbonatation.**—This operation is conducted in the same appliance as the first carbonatation. The manner of conducting it offers no points of special importance, and the transformations are very much the same as in the first carbonatation though there is less frothing.

The second carbonatation, if properly conducted, can easily be made continuous by employing three tanks, or two tanks and a reheater, the juice overflowing from one to the other. The juice after being thoroughly heated in the reheater overflows into the first tank, where it is finally carbonatated after having had lime added; it is then pumped into the second carbonatation tank and a third saturation is effected as was the second, the essential condition being a high temperature.

**Alkalinity of juices.**—Another point which has been much discussed is the limit of alkalinity to which these juices should be saturated. Some authorities claim that there are advantages in a high alkalinity, while others recommend that the saturation be continued until the juices are nearly neutral. In settling this question one should take into consideration the behavior of the alkaline and neutral juices during evaporation, and the precipitation of the substances comprising the non-sugar during saturation, not only in diluted but in concentrated juices.

According to ANDRLIK * it is desirable during second carbonatation not to allow the alkalinity to fall below a certain limit, so as to avoid redissolving the substances not eliminated during third carbonatation. Among these elements magnesia may be mentioned. During the campaign of 1898–1899 an example was given of a *triple effect* being so charged with deposits that it became necessary to wash it with acids every few days. In this case it was customary to leave in the second carbonatation an alkalinity of 0.03 to 0.04 per cent in CaO and in the third 0.005 to 0.01 per cent. The juices upon leaving the third compartment of the apparatus were cloudy and left an abundant deposit when filtered. The analyses for 100 cc. of juice were as given in the following table.

These figures show that the amount of magnesia present in the juice is greater after the third carbonatation than after the

* La. S. B., 30, 86, 1901

| Carbonatations. | Alkalinity. | | |
|---|---|---|---|
| | CaO. | AzH³. | MgO. |
| | Gr. | Gr. | Gr. |
| First. . . . . . . . . | 0.008 | 0.012 | |
| Second. . . . . . . | 0.035 | 0.009 | 0.0041 |
| Third. . . . . . . . | 0.007 | 0.007 | 0.0057 |

second. The deposits on the filters contained 23.69 per cent of magnesia calculated to a dry basis. The composition of the juice and the deposits in the triple effect showed beyond doubt that the incrustations were due to the precipitation of carbonate of magnesia. A maximum alkalinity of 0.05 to 0.06 per cent CaO has been proposed in order to prevent the magnesia from entering the juice. It was thought that an alkalinity of 0.035 per cent would show that all the free lime had been precipitated.

During evaporation juices are generally submitted for a time to a temperature higher than 100° C., reaching in many factories as high as 115° C. or even 120° C. before reaching the vacuum pan, and in the first compartment of a multiple effect it is higher than 100° C. It is certainly very imprudent to submit neutral or slightly alkaline juices to such high temperatures, as the alkalinity always decreases during evaporation.

CLAASSEN says that neutral juices generally become acid, this change being followed by an appreciable decomposition of sugar, made evident by an increased coloration of the juice. On the other hand, juices that are in the proper condition of alkalinity do not show any sugar decomposition when the temperature does not exceed the limit of about 115° to 120° C., but undergo an amelioration, for the reason that the alkalies have an energetic action upon the decomposable substances, such as amides and albuminoids, which have not been transformed or eliminated by defecation. Alkaline juices, however, show a very perceptible alkaline retrogression, which, however does not reach neutrality and is not the outcome of sugar decomposition, but is due to the combination of alkaline with acid substances, which are the outcome of non-sugar and to the volatilization of the ammonia that has been formed. Consequently during evaporation the changes which take place should be effected in strongly alkaline juices if time and space permit.

ANDRLIK * declares that carbonatated juices cannot retain their alkalinity if the proportion of non-volatile alkaline bases remaining to saturate the amide acids is not at least 3.3 times greater than these acids, as then the alcalinity would not be due to these bases and the juice would only have an alkalinity due to ammonia. It is pointed out, furthermore, that there is a method of ascertaining whether the juices are about to lose their alkalinity, which consists in the estimation of the calcic salt with hydrotrimetric liquor, as any increase in these salts corresponds to the decrease in alkalinity. Sometimes there is to be noticed an increase in the alkalinity, and this is attributed to a supersaturation of the juice which then contains an alkaline bicarbonate which has remained without action upon the phenolphthalein, and later is transformed into a neutral carbonate through the elimination of carbonic acid and gives an alkaline reaction. On the other hand, NEUMANN † recommends that the juice be saturated in the presence of phenolphthalein to determine whether there is a loss of alkalinity until the limit of neutrality is reached, leaving, however, a slight red coloration. When the juice is boiled, the coloration disappears and a certain quantity of a normal sodic solution is necessary to obtain the neutrality. Normal juices do not show this phenomenon. It has been recommended and tried in several beet-sugar factories with some success that the maximum temperature of the diffusion battery be located not in the last but in the first section containing the fresh cossettes. According to these authorities it is mainly the exhausted cossettes which yield the substances that seem to absorb the alkalinity. The results obtained have not been equally satisfactory in all cases in which this mode has been adopted.

Experience shows that the juices should be kept alkaline, and that they should remain so after they have been concentrated. It is consequently unreasonable to prescribe a determined alkalinity for fresh juices; this should vary with the composition of the juice and its behavior during evaporation, and it is always impossible to indicate the limits. The maximum limit occurs when an alkalinity already exists, due to free lime oxide or to saccharate of lime, while the minimum limit should be regulated according to the alkalinity of the concentrated juice or syrup, or of those partially concentrated but not saturated. If one

* B. Z., 25, 143, 1900; B. Z., 23 711, 1899. † B. Z., 23, 718, 1899

finds that a standard of 0.05 to 0.01 or more appears reasonable the alkalinity of the juice should be increased as the alkalinity of the syrup declines, or it should be reduced as soon as the concentrated juices are excessively alkaline. Generally when the alkalinity of the juice varies from 0.03 to 0.05, as shown by the phenolphthalein test, there is no free lime, or at least very little present, but frequently a considerable quantity is combined with the acids. The greater part of the alkalinity is the outcome of fixed or organic bases of ammonia. When working inferior beets, or at least such as are not thoroughly matured, the condition or nature of the juice demands an energetic action upon the alkalies, or the introduction of lime in the evaporating appliances. Under all circumstances the highest possible limit should be selected as a standard for the alkalinity of the concentrated juices. Allowance should be made for the fact that in such cases strongly alkaline juices generally leave a considerable deposit in the evaporating appliances. If the evaporation decreases the alkalinity should be reduced.

Claassen says that there is no difference in purity and the working up of any juice, whether with this proposed excessive alkalinity one effects the last saturation of juice with carbonic or sulphurous acid, owing to the simplicity and ease with which these operations may be accomplished. Preference is generally given to carbonic acid and the sulphuring is mainly applied to concentrated or to the half-concentrated juices. If one finds that there are advantages in resorting to a triple carbonatation the alkalinity of the first carbonatation should be kept within the limits of about 0.01 or 0.02 per cent higher than the standard of final juices so that the second carbonatation will result in the desired epuration.

Upon general principles it may be admitted that the alkalinity after the second carbonatation varies in different factories within the limits of 0.01 and 0.06 per cent. When the triple carbonatation of Karlik is applied the following alkalinities are maintained with normal juices, which will undergo little or no change during subsequent working: Carbonatation is stopped when the juices still retain 0.08 per cent of lime as a minimum; for second carbonatation the amount of lime used varies from 0.2 to 1 per cent of caustic lime; the flow of carbonic acid is stopped when the alkalinity is 0.05 to 0.06 per cent; for third carbonatation an alkalinity of 0.02 to 0.03 per cent may be reached. The juices

of second carbonatation are frequently reheated after the operation in the carbonatation tanks, special steam coils being used for the purpose.

**Filter presses for second carbonatation.**—When there are three saturations there should always be two filtrations so that the juice sent to the evaporating appliance may be perfectly clear. For the first filtration the standard filter presses having a tightly woven cotton or hemp fabric for a filtering medium are generally used.

A special scum pump is used, or one is attached to the same engine as that employed for the cloudy juices of first carbonatation, which forces the second carbonatation juices through the filter presses. The general construction of these presses does not differ from those previously described, but they will work for a longer time without the necessity of renewing the filtering cloths. The washing of the residuum scum of second filter presses is conducted in the manner previously described.

Claassen maintains that for this filtration it is desirable to use presses without the usual water passages, which possess certain disadvantages. For example, when the juice running from the presses is cloudy there is no way to isolate the compartment causing the difficulty. If the cock through which the cloudy juice flows is closed it will run into the passages in which the sweet water circulates, thus entering the other compartments and clouding the entire filtrate. On the other hand, presses of very simple construction allow the circulation through the carbonatated juice passages only. Presses with water passages are generally not considered desirable for the second carbonatation juices. If no lime is added to the juice the quantity of scum obtained is very small, not more than 0.1 per cent of the weight of the total beets sliced, and the sugar loss, even with rich beets, is so slight that it need not be considered. If, however, one obtains a considerable amount of scums, owing to the lime added, it becomes desirable to run them into the first carbonatation tanks rather than to attempt their working in the second presses. When run in second presses it is sufficient to force steam through the scums.

The sugar percentage of second carbonatation scums which have been submitted to the action of steam, but not washed, is generally high and varies from 4 to 7 per cent, as it nearly always contains insoluble saccharate of lime. This mode of working, however, increases the work of the general handling of the filter presses of the first carbonatation.

**Perturbations in the working of filter presses of second carbonatation.**—The filtration of the second carbonatation scums may be accomplished without difficulty and demands but a small filtering surface. However, it may happen that after a short time the filtrate will flow very slowly and a complete scum cake will not be formed. The deposit, which will be mainly upon the filtering cloths, will be of a very viscous texture. This complication does not generally show itself unless the scums were difficult to filter during first carbonatation owing to the carbonic acid treatment being pushed to an excess. Under these conditions carbonate of magnesia is dissolved and again precipitated during second carbonatation and this, as well as other insoluble magnesia compounds, always has a gelatinous consistence and renders the filtration more and more difficult as its quantity increases in proportion to the amount of calcic carbonate present.

It is to be noted that the filtering cloths of the presses for second carbonatation juices have a strong tendency to clog very much more than during the first filtering, for the reason that during the operation the saturation is frequently pushed to such a limit that bicarbonate of lime is formed, which when decomposing will clog the cloths. On the other hand, if the juice of second carbonatation contains too little lime the flow from the filter presses is not satisfactory. Although this difficulty is never so great as during first filtration, as fewer presses are used for the second carbonatation juices, it may cause a considerable waste of time in the process of sugar extraction. The scums of the second carbonatation filter presses contain very much less non-sugar than the first. They are soft, white and chalky, and separate readily from the filter-press cloths, but are inferior for agricultural purposes.

## CHAPTER VI.

### MECHANICAL FILTRATION OF JUICES AND SYRUPS.

THE mechanical filters used in beet-sugar factories may be classified as follows: A. Filtration through filtering cloths, including (1) pockets filtering from the interior to the exterior (Taylor, etc.); (2) a type having the same arrangement as filter presses; (3) pockets filtering from the exterior to the interior; (4) continuous filtration; (5) various combinations. B. Filtration through granulated substances, including (1) sand; (2) infusorial earth, wood powder; (3) other granular and fibrous substances, such as peat, asbestos, etc.

**Importance of filtration.**—Even though no subsequent difficulty is to be feared in working a cloudy filtrate from the first filter presses, the same cannot be said of the juices running from the second presses, for if these are cloudy incrustations within the tubes of the multiple effect result. Hence the filtrate from second filter presses is submitted to a mechanical filtration, some manufacturers repeating the operation many times during the subsequent phases of the manufacturing processes. In certain beet-sugar factories coming under the writer's notice it is customary to resort to mechanical filtration of the juices from the first filter presses, but in most cases it follows the filtration of the second carbonatated juices. If sulphuring is employed it should be applied to the second filtrate direct and be followed by mechanical filtration before evaporation. When juices which have been partly concentrated during their passage from one of the compartments of the multiple effect are sulphured the operation must be followed by a mechanical filtration. In some factories the juices are filtered at every stage of their passage through the evaporating appliance. Again, it is the custom to filter the syrups before graining in pan and the after-products before they are returned to pan. As impurities contained in juices and syrups prevent the final sugar from crystallizing, the more complete their elimi-

nation the greater will be the ultimate yield and the better the quality of the sugar obtained.

The nature of the substances separated from the juices during filtration is shown in the DONATH * analysis.†

* N. Z., 26, 206, 1891.

† The composition of the deposits from the mechanical filtration of the filtrates from second filter presses is as follows:

| | Per Cent. |
|---|---|
| Substances soluble in water | 7.12 |
| Fatty substances | 2.45 |
| Combined fatty substances | 0.90 |
| Carbonic acid | 36.41 |
| Ash less $CO_2$ | 52.34 |
| | 99.22 |

Composition of ash:

| | Per Cent. |
|---|---|
| Silicic acid | 0.45 |
| Copper oxide | 0.12 |
| Ferric oxide and alumina | 1.94 |
| Magnesia | 2.03 |
| Potash | 1.06 |
| Soda | 0.30 |
| Sulphuric acid | 0.38 |
| Carbonic acid | 10.75 |

This analysis shows that these deposits should have been separated in the filter presses. DONATH also analyzed the deposits from the mechanical filtration of the syrups with the following results:

| | | | |
|---|---|---|---|
| Organic substances | 71.70 | Sugar | 44.68 |
| | | Fatty substances | 9.16 |
| | | Fatty acids | 4.67 |
| Carbonic acid | 8.58 | | |
| Ash less $CO_2$ | 19.68 | | |
| | 99.96 | | |

The composition of the ash was:

| | Per Cent. |
|---|---|
| Silica | 47.12 |
| Carbonic acid | 2.10 |
| Copper oxide | 2.73 |
| Lime | 1.59 |
| Ferric oxide | 1.12 |
| Alumina | 18.52 |
| Phosphoric acid | 0.39 |
| Sulphuric acid | 1.64 |
| Potash | 18.74 |
| Soda | 3.21 |
| Chlorine, magnesia, and manganese | traces |
| | 97.16 |

The analysis of the ash shows that these deposits arè composed of those substances which becôme insoluble during evaporation. DONATH claims that the ferric oxide found in the deposit will act as a mordant upon the filtering cloths by fixing certain coloring substances.

Particles of scum find their way through the filtering cloths of the second filter presses with fresh cloths or with torn ones, and deposit upon the tubes of the multiple effect, thus reducing their efficiency. The organic substances contained in these particles of scum, after a time and under the influence of heat, will decompose and impart a dark color to the juice with which they come in contact. However, certain organic salts, such as calcic oxalate, are very much less soluble in concentrated than in diluted juices, and are consequently precipitated during evaporation which shows the importance of their separation by a thorough filtration. The syrup filters are very much like those used for the filtrates from the second carbonatation filter presses.

**Which juices should be filtered** is a question that has not yet been settled by the leading experts. But one fact is certain, every effort should be made to free the juice completely of its impurities before entering the multiple effect. How this is bes accomplished depends upon a number of factors which necessarily vary from factory to factory. Even after the juice leaves the evaporating appliances the importance of filtration is as great as it was during the earlier stages of epuration, as the impurities, if not removed from the syrup, will impede satisfactory graining in the vacuum pan. EICKEL states that as filtration of thick syrups is very difficult he prefers filtering the syrups during one of the stages of concentration at 17° or 18° Bé. These syrups are from the last compartment but one of the multiple effect. CLAASSEN * takes exception to this assertion, and points out that syrups even at 60° Brix may be readily filtered when hot, provided their alkalinity is not too low. It is possible to filter a syrup having an alkalinity of 0.15 to 0.20 per cent in which the alkalinity after sulphuring is reduced to 0.05 per cent of lime.

**Boneblack. General considerations.**—Up to 1880 no other mode of mechanical filtration was known than that performed in large cylindrical receptacles filled with boneblack. The decolorizing action of boneblack was followed by a mechanical filtration of the juice through the char granules. So much stress was placed upon the decolorizing action of boneblack, which theory was accepted by most sugar experts, that it seemed improbable that the time would ever come when the filtration of juice or syrup

* C., 7, 804, 1899.

would be accomplished without its use. Then for years there were endless discussions as to whether the decolorizing action actually existed. The question has now been settled, and the product is used only in exceptional cases and in no modern beet-sugar factories. Even in sugar refining there is a tendency to do away with boneblack entirely.

Sand filtration proved the final blow to the use of boneblack. MEYER * observed that juices filtered on sand showed very little difference from those on char. Other investigations were made, and it was noticed that unless the boneblack filtration was properly conducted the juices instead of being ameliorated lost certain essential qualities, and that the sugar losses with boneblack were considerable, for the reason that the char retains a certain quantity of sugar in a more or less combined state, and also the boneblack cannot be sufficiently washed to remove all the juice absorbed, as excessive washing dilutes the juice and causes an ultimate increase of the fuel necessary for evaporation. The sugar still remaining in the boneblack had to be destroyed through fermentation, which operation was long and dirty and in most cases it was neglected. The same may be said of consecutive washings with water and hydrochloric acid, and the cost of bone-kiln revivification was expensive also. Hence it is no wonder that at the present day very few manufacturers return to this almost obsolete mode of decoloration and filtration, and it seems useless to discuss the subject further.

**Pocket filters.**—While sand filtration as a substitute for boneblack was a new departure in the method of filtration for the second carbonatation juices, the TAYLOR types of pocket filters came into vogue. The idea was considerably improved upon by PUVREZ (Fig. 224), by whose arrangement several bags are placed beside

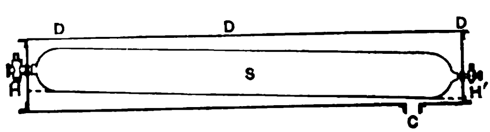



FIG. 224.—PUVREZ Pocket Filter.

one another resting upon perforated sheet-iron troughs in a special compartment *D*. Each of these filters consist of a long, thick cotton bag *S*, the extremities being tightly held upon the pipes con-

* Oe.-U. Z., 8, 641, 1879.

necting respectively with the cocks $H$ and $H'$. The juice to be filtered enters at low pressure through $H$, and the other cock $H'$ is used to empty the bag when full of mud. The cotton bag $S$ is slightly slanting, $H'$ being a fraction lower than $H$, thus facilitating the evacuation of deposits during emptying. The filtrate runs out through the bottom opening $C$. One of the objectionable features of these filters was that the filtering surface was very limited, and frame-filter combinations took their place.

**Frame filters.**—NAGEL * proposed that for this filtration the ordinary filter presses be employed, and these appliances were used for some years and gave reasonable satisfaction. PUVREZ devised a similar combination, and while that of WEGELIN and HUEBNER did not differ from the filter presses in its general working it was entirely made up of frames without plates. The frames were in pairs, and the juice after having passed through one thickness of filtering cloth was compelled to run through a second thickness.

The LOZE and HELAERS † (Fig. 225) filter also had the general

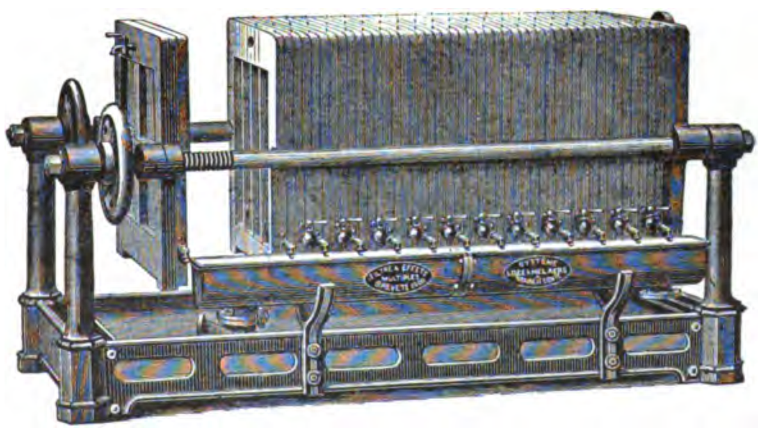


FIG. 225.—LOZE and HELAERS Frame Filter.

aspect of a filter press, and was made up of a considerable number of frames but no plates, divided into four sections by three vertical cross bars which at the same time served to keep the filter cloths in position. The frames were divided into three series, which communicated through suitable openings and were known as entrance,

* Z., **31**, 599, 1881.

† LOZE et HELAERS, Le travail sans noir, Bruxelles, 1886

middle and exit frames. The first series could be emptied through a number of pipes which were generally closed. The middle series had no pipes and the exit cluster had suitable cocks for the outward flow of the juice, which before leaving this combination underwent two filtrations. One of the advantages claimed for this filter was that the wear on the filtering cloths was reduced to a minimum. It possessed, however, some very objectionable features, as the wooden frames in time became saturated with the sweet juice and formed a centre for microbe infection. The iron-frame filter presses, however, were considered too expensive for mechanical filtration.

Upon general principles it may be said that filter presses are not as desirable for the second carbonatation juices as are pocket filters, or an apparatus giving considerable filtering surface with a comparatively small volume and allowing the filtration to continue at a rather low pressure, which is one of the essential conditions for retaining on the filtering cloths the excessively fine particles of scum.

The main characteristic of the old types of the TAYLOR pocket filters was based upon an erroneous idea, which was to collect the deposits in a bag made of some filtering tissue. BELCHER * originated the idea of filtering from the exterior to the interior of these bags or pockets. In a large cylindrical receptacle was placed a series of pipes with numerous holes, over which there was a cylindrical cotton covering. The juice entered the filtering cylinders under pressure and escaped from their interior, the particles in suspension being separated on the outer surface of the cotton filtering medium. When the deposits reached a certain thickness they fell by their own weight to the bottom of the cylindrical casing. The same idea with some few modifications was carried out by BOLIKOSWKI.† The most objectionable feature of all arrangements of this kind is their very limited filtering surface. This difficulty was largely overcome by the use of a new kind of pocket filter made somewhat like a pillow-case and stretched upon the surface of a frame with metallic lattice work. This arrangement was used by SEBOR ‡ as early as 1872, and is almost identical with those now in vogue.

The standard type of the bag-filters is that of PROKCH, as

* Z., 30, 40, 1880.

† BEAUDET, SAILLARD and PELLET, Traité, I, p. 383, 1894.

‡ Oe.-U. Z., 20, 438, 1891.

made by BREITFELD and DANEK (Fig. 226). It consists of a small cistern which is hermetically closed with a cover having a counterpoise attachment. In the receptacle are suspended a series of nearly square frames made up of flat iron bent over in U shape. The two open portions of the U end in front of the exit pipe which has a corresponding opening or longitudinal slit; from it an undulated plate of sheet iron penetrates into the interior of the U. A

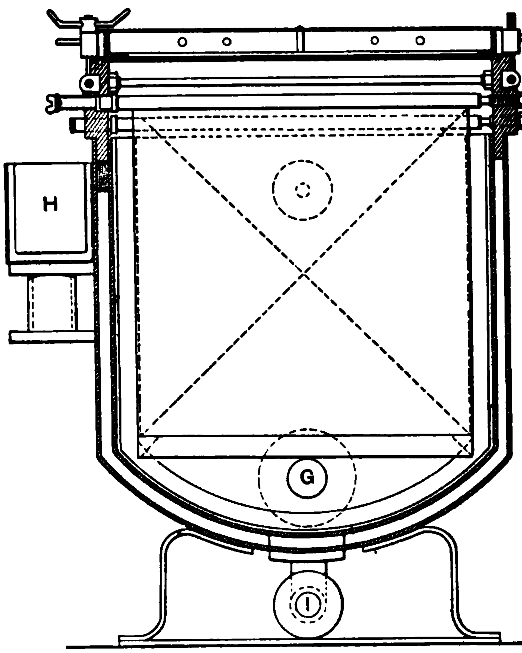



FIG. 226.—BREITFELD and DANEK Filter.

sort of pillow-case is passed around this frame and its upper border is turned over the exit pipe. An iron bar, not shown in the engraving, presses the filtering cloth against the surface of the horizontal suspending pipe and thus forms a tight joint. One extremity of this pipe is closed, but there is a small depression into which the end of a bolt penetrates. The other end is open and connects with a small pipe, through which the filtered juice runs into the trough *H*. The communication may be closed when the filtrate is cloudy. The juice to be filtered enters the apparatus through *G*. When the filter needs cleaning steam or water may be introduced through the same pipe, and the emptying is done

through *I*. It is to be noted that the flat irons have the sole object of keeping the cloths in their vertical position.

In a filter of yet another design (Fig. 227), but devised by the

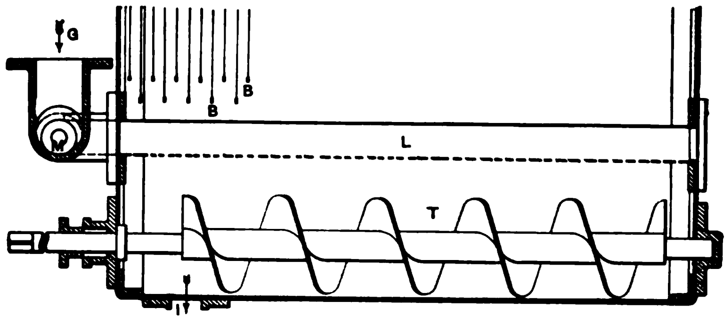



FIG. 227.—Spiral Device for Emptying.

same constructors, the juice slowly enters the receiving receptacle by the pipe *L*, which has bottom openings, and then flows upward through the filtering cloths *B*. Owing to the slowness of the circulation the deposits at the bottom are not disturbed. When there is a sufficient quantity they may be removed from the apparatus by simply giving six or seven turns to the screw *T*, the escape being through *I*.

DANEK has introduced many important modifications of his filters. The exit pipe for the juice has two projecting lips 15 and

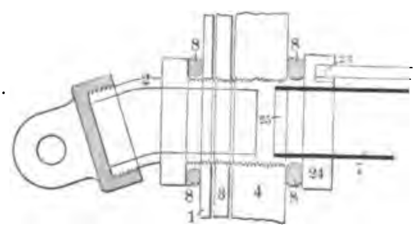


FIG. 228.

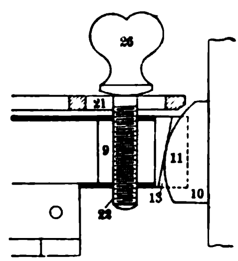



FIG. 229.

16 (Fig. 230) in its longitudinal direction, to which is bolted the metallic framework 6 supporting the filtering cloths. In the old filters these frames penetrated the pipe and diminished its interior capacity. The tightening of the filtering cloths is effected by a rod 20, the end of which, 23 (Fig. 228), is pushed into the corresponding opening of 24. This is either fork-shaped or has an opening with an eyelet for tightening the screw 26 (Fig. 229). The filtering

cloth may be removed by turning the screw about 90°. Yet another improvement to facilitate the passage of the circulating filtrate from the bottom to the top in the frames consists in having small slits in the sheet iron at regular intervals from top to bottom. By this arrangement various shapes may be given to these passages, as shown in Fig. 231, front view, Fig. 232, the side view, and in Fig.

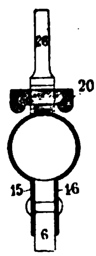



Fig. 230.

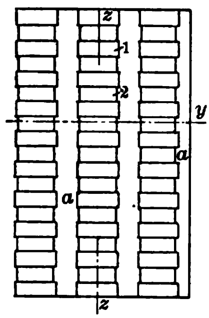



Fig. 231.

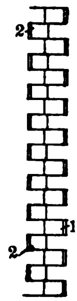



Fig. 232.

Fig. 233.

233, a horizontal section *Y*. The Danek filters can handle from 90 to 100 hectoliters per square meter of filtering surface a day; but it is to be noted that their efficiency varies considerably with the quality of the juice and the nature of the filtering surface.

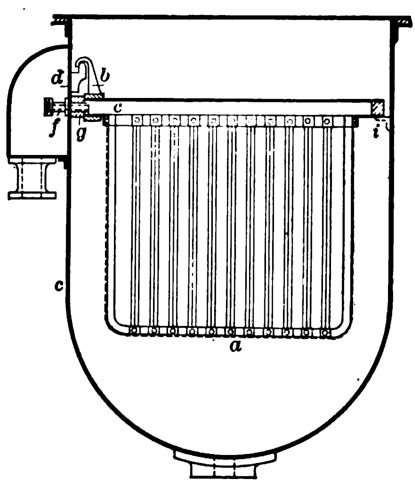



Fig. 234.—Scheibler Filter.

The Scheibler filter (Fig. 234) has many of the same characteristics as the Breitfeld and Danek apparatus, but the tight-

ness of the joint of the exit pipe is obtained through the weight of the frame. On the same side of the frame is a hook *b* for suspension to an upper rail *d*, or to a ring fastened to the general frame *e* of the filter. The joint *g* surrounding the evacuation pipe is rubber and is held tightly in position by the weight of the frame itself which acts as a sort of lever, thus increasing the pressure. To prevent the entire weight of the frame from pressing upon the rubber joint the other end is held up by a special

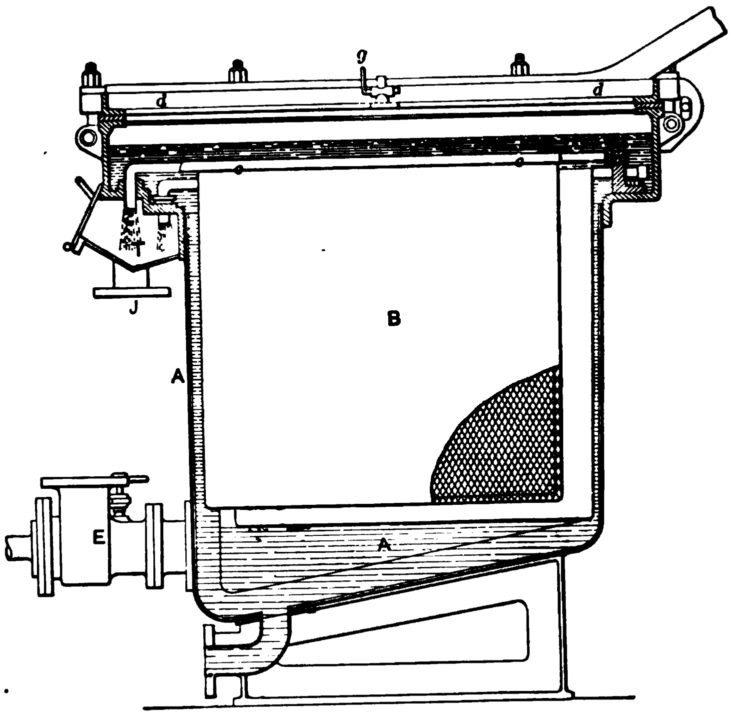



FIG. 235.—KASALOWSKY Filter.

regulating device *i* by which the pressure can be regulated to suit the emergency.*

The KASALOWSKY filter is another example of the same type as the BREITFELD and DANEK filter (Fig. 235). Each frame *B* consists of a galvanized metallic spiral made up of wires of suitable diameter, and these are riveted to a pipe *c*, one end of which rests

* Z., 51, 762, 1901.

on a transverse support, *m*, while the other end being bent downwards enters the emptying box *T*; the felt joint of the border of the latter with the pipes is satisfactory. The top cover *d* has a counterpoise. The filtrate escapes through *T*, the deposits are removed through the bottom pipe, and the juice enters the compartment *A* at *E*. The circulation is regulated by the valve *E*.

The mounting and unmounting of these filters is very easy as the frames are simply suspended and may be withdrawn or replaced as occasion demands. The filtering cloth rests against the spiral wire and at least 90 per cent of its entire filtering surface may be utilized. Experience has shown that in many of the filters using undulated sheet iron in the frames the filtering cloths offer obstructions to the passage of the juice when under considerable pressure, and, therefore, excessive pressure in such filters is not desirable.

The filtering bag (Fig. 236) is closed above the exit pipe *C* by doubling over the two borders *a*, the ends *x* and *y* being covered with a zinc cap *z*. This apparatus has 46 frames, each of which has 1 square meter of filtering surface and will work 100 hectoliters of juice in twenty-four hours, or 35 hectoliters of syrup at 25° Bé. or 30 hectoliters at 30° Bé. in the same interval. This device has been used in France in several instances.

FIG. 236.

The MAERKY, BROMOWSKY and SCHULZ (Fig. 237) filter has frames consisting of two sheet-iron plates with suitable perforations, between which there is a sufficient space to allow the filtered juice to circulate readily. The covering of the exit pipe is effected as in the case first mentioned, but the ends of the bags are held

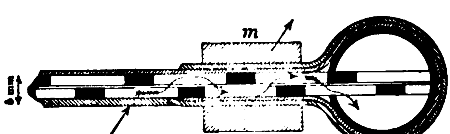



FIG. 237.—Horizontal Section of the MARKY, BROMOWSKY, and SCHULZ Frame.

tightly against the frame by two small rods *m* tightened by a screw. One of the SVOBODA * apparatus, has the special character-

* B. Z., 12, 17, 1887.

istic that the exit pipe is vertical instead of horizontal as in the other mechanical filters of the same kind. This arrangement has now become obsolete.

Of late years the CLARITAS filter (Fig. 238), invented by MATOUSEK and BERUNSKI, has been used a great deal. This mechanical

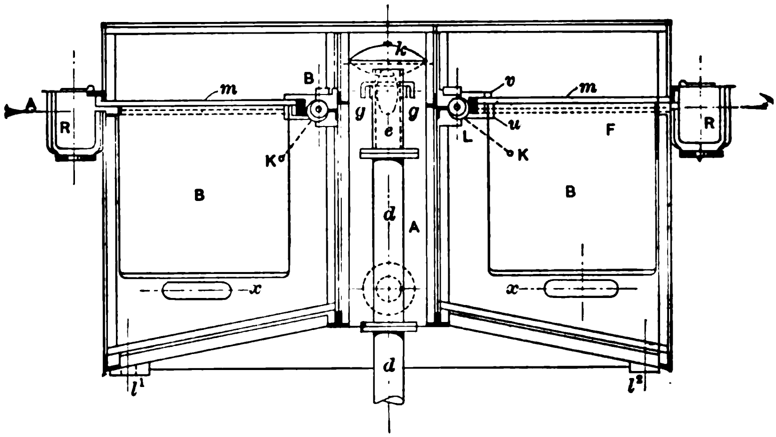



FIG. 238.—CLARITAS Filter.

filter has one important feature, namely, the enormous number of frames of which it consists. It is made up of four filters $B$, one in front of the other, each of which works separately, but all receive their juice from a central distributor $A$. The float $K$ regulates the level in $A$ through the valve $g$, which stops the entrance of the juice in $d$. The joint of the canal $m$ with the outer side is closed by the pressure exerted by the cams $K$, which may be adjusted from the exterior and acts upon all the frames at once. This press may work at a low pressure.

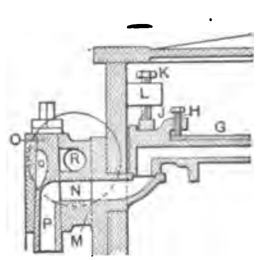



FIG. 239.

Before considering another type of pocket filter it will be interesting to note some modifications which have been made in the KASALOWSKY filter by FEUILLEBOIS (Fig. 239). These changes may also be applied to other filters of the same kind. A special cock permits either a steam or a water circulation from the interior to the exterior, or, in other words, in a direction opposite to that of the juice, the object being to detach the deposits from

the surface of the filtering medium. The faucet of this cock has a cavity $Q$, which when turned 180° brings the pipe $R$, which extends along the entire length of the filter, into communication with $N$ and with the interior of the frame. When it is noticed that the exit flow of the filtered juice is comparatively small $Q$ is placed so as to allow steam to be run into the interior of the pocket and its action soon opens up the passages of the filtering surface. If this washing is not effectual hot water is used. Under steam pressure the joints of the circulation passages would no

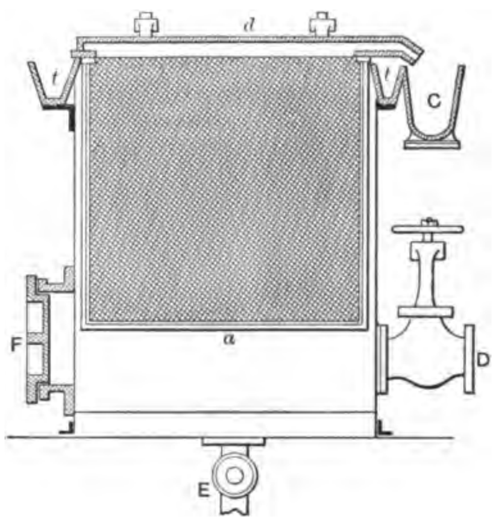



FIG. 240.—SVOBODA Filter.

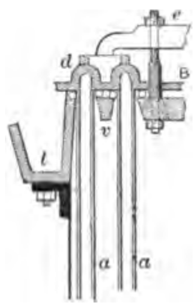
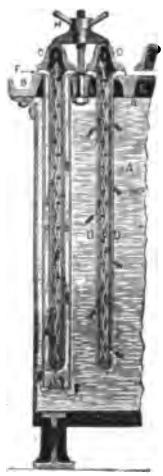



FIG. 241.

longer be sufficiently tight, and the simple weight of the filter-press frames could not be depended upon. The bolt $K$ overcomes the difficulty by pressing against $J$. In the same way the nut $H$ keeps the filtering cloths in position by pressing upon the rod $G$.

The SVOBODA (Fig. 240) arrangement is another important innovation. In this filter it is the frame itself that hermetically closes the receptacle into which the cloudy carbonatated juice or syrup enters under a slight pressure through the valve $D$. The upper part of the frame through which the liquid circulates consists of a strong iron casting $d$. In Fig. 241 is shown an enlarged section of the frame and the attachments of the press under consideration. The frame covered by the cloth $a$ passes through the upper plate $V$ of the receptacle and is held down by the iron cover $d$,

thus forming a tight joint. The brace *e* with suitable nut permits a satisfactory tightening. The upper border of the cloth is properly hemmed, and in its interior is a strip of hemp or rubber which tightens the joint. All around the upper plate *V* is a small gutter *t* intended to collect the juice that escapes through the joints. The filtrate runs through *d* into the gutter *C*. The deposits may be withdrawn through the emptying cock *E*. As to the frame itself, it consists of a flat iron bent ⊔ shape and attached to *d*.



Vertical Section.

Fig. 242.

Transverse Section.

Fig. 243.

Philippe Filter.

In its interior is the metallic cloth which keeps the filter cloths well separated.

The Philippe (Figs. 242 and 243) mechanical filter in its general working is the same as the one just described, the circulation of the juice, however, is different. In the juice is suspended a series of bags covering wire frames, which are held in position by the pressure exerted by *G* on the border *F*. In the interior of *G* is a horizontal pipe through which the juice circulates, thence running through *I* into *K*. The nut *H*, with handles, when screwed into position keeps two frames with their bag covering in place. The movement of the circulation of the juice is consequently as follows: The product to be filtered enters the reservoir near the middle of the side, descends along the sides *L*, between which the

frames are suspended, and rises to come in contact with the filtering surface. Under these circumstances there can be no possible danger of a direct current between the point where the juice enters the filter and the nearest filtering frame, and all the frames thus receive the same quantity of juice or syrup which passes through the filtering medium into the interior of the pockets *D*, penetrates the caps *G*, etc. The impurities fall to the bottom and may be removed through a special side manhole. To change the filters stop the juice circulation, slightly unscrew *H* without removing it,

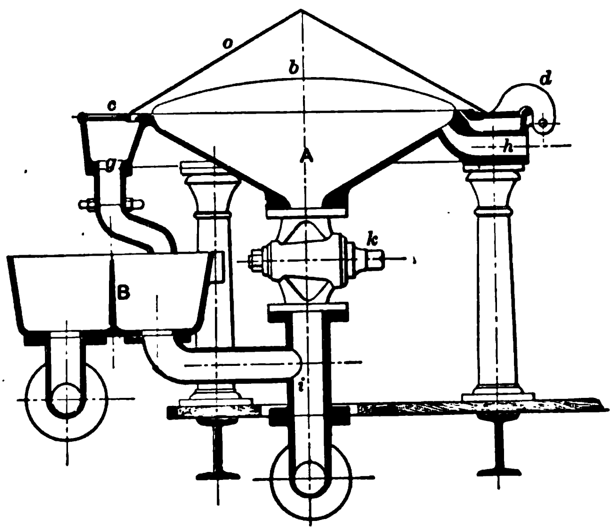



FIG. 244.—VONHOF Filter.

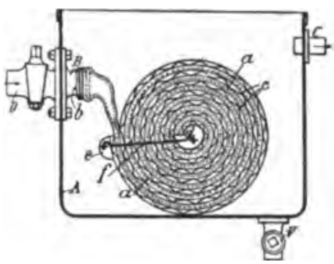
lift *G*, *G*, etc., from their positions, remove the filtering sacks, replace them by fresh ones and tighten the nut *H*. MARES * prevents dead spaces on the surfaces of pocket filters by introducing the juice through different openings of the frames so as to obtain everywhere a slight motion of the liquid, not sufficient however to detach the deposited scums from the filtering surfaces.

There are a large number of other filters with filtering cloths very different from those just described. Among these may be mentioned the VONHOF † filter (Fig. 244), that at one time was much used in Germany. It is closed by two superimposed conical boxes, *A* and *O*, between which is pressed a round filtering cloth

* Oe.-U. Z., 28, 643, 1899 † Jahrb., 25, p. 83, 1883.

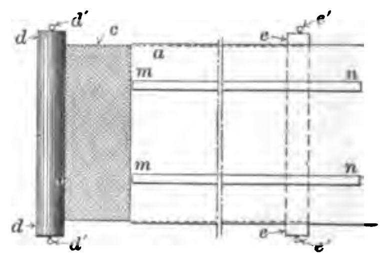
*b*. The juice enters through *h*, passes through *b*, and flows into the trough *c* through openings made in the periphery of *O*. As long as the filtrate is cloudy it is allowed to return through *B* and the pipe *i* to the receptacle from which it was taken. When the filtered juice or syrup is perfectly clear the arm connecting with *g* is turned towards the outer section trough alongside of *B*. When it is desired to empty the deposits collected in *A* the cock *k* is opened. The cloths of this filter may be rapidly renewed, as the cover may be opened around the hinge *d*. The very limited filtering surface of this mechanical filter has caused it in a measure to become obsolete.

In France the BRIDE and LACHAUME filter (Fig. 245) has also had some success. It consists of a cotton sack or pocket *a* without



End View, Wound.

FIG. 245.



Top View, Open.

FIG. 246.

BRIDE and LACHAUME Filter "Snail."

side seams which may be attached to the entrance pipe *b*. In the interior of this sack is a wire grating *c* intended to keep the sides of the sack well apart so that the circulating liquid will have the least possible resistance to overcome. In Fig. 246 is shown the sack spread out on a horizontal surface. It is 60 cm. in width, and before being used and placed in position in the receptacle *A* it is rolled up on the central cylinder *dd'*. In that position it has a diameter of 35 cm. and a filtering surface of 6 sq. m. *M* and *n* are flexible strips placed upon the outer surface of the bags or pockets to keep them well apart. When exactly in position the roller *ee'* is placed on the outer surface and held in position by the bar *f*. The filtered juice escapes at *c*, and the mud, etc., that has been deposited may be removed at *V*.

The advantage of one filter over another depends mainly upon the facility with which the filtering cloths may be renewed and the cloths or bags made perfectly tight. In the latter respect and

upon general principles it may be said that all the apparatus now used for mechanical filtration give about the same efficiency. The main object now to be considered is that they may be readily taken apart, and in all the modern combinations the handles of the frames greatly facilitate this operation.

In front of each filter for non-concentrated juice there should be two gutters, one for the perfectly clear juice, which subsequently flows into the evaporating appliance, and the other for the cloudy filtrates which run off in considerable quantity when the presses are first started, and may be sent to the second carbonatation tanks. This combination is found in most mechanical filters.

**Influences of pressure.**—The mechanical filters are comparatively small, as the amount of material to be eliminated is very much less than in the filter presses, and for this reason the pressure is also comparatively small. A very limited pressure is one of the essential conditions for the satisfactory deposit upon the filtering cloths of the impurities in question. In most cases the filters under consideration are placed 2 or 3 meters below the reservoirs containing the filtrate of the second carbonatation filter presses. At the present day this pressure is even less, and the BREITFELD and DANEK filters are not even closed on top. The juice cistern is placed 50 cm. above the frames of the press. The filtration may even be satisfactorily accomplished with a pressure of 30 to 40 cm. In the case of the CLARITAS filters, they work under a pressure of 10 to 40 cm. Under these conditions the velocity of the circulating liquid is comparatively slow, which fact may be compensated for by increasing the filtering area. Filtration under these very low pressures has rendered practicable the idea suggested by PIEDBŒUF * which was to place a filtering appliance between each of the compartments of a multiple effect.

**Concentrated-juice filtration.**—The filtration of half-concentrated juices is to be recommended if they show after being partly evaporated considerable calcareous precipitates which would subsequently deposit upon the heating tubes.
show considerable calcareous deposits, which consist mainly of precipitates formed by the evaporation of non-concentrated juice and subsequently deposited upon the heating tubes.

This half-concentrated juice is filtered by placing a closed filter (gravel, sand, boneblack, or a closed press) between the

* Jahrb., 8, 172, 1868.

last compartment of the multiple effect and the preceding one. The juice then passes through the filter, circulating from one compartment to another. This arrangement frequently gives considerable trouble, as the difference in pressure is not sufficient for the filtration. In this case no saturation is effected previous to each filtration.

**Influence of concentration.**—Generally the concentrated juice or syrup is readily filtered. However, some concentrated syrups, especially those kept at a density greater than 60° Brix, are difficult to filter and in some cases it cannot be effected at all. It is then recommended to saturate and filter the juice of a moderate concentration, that is to say, as it is in the compartment before the last of a multiple effect. The juice that has a density of about 30° Brix is pumped into the saturation tank, and the treatment is the same as that previously described for concentrated juice. The filtrate is then drawn into the last compartment of the apparatus where the concentration continues in the ordinary way. Usually under these circumstances the juice becomes cloudy, but the bulk of the scums has already been sufficiently separated by filtration, provided the installation for this operation is up to the desired standard. In that case there need be no filtration of the concentrated juice.

It may sometimes happen that the exit flow from the mechanical filters is comparatively slow. Under such conditions it would be a grand mistake to attempt to increase the pressure in order to increase the circulation and the results obtained would be disappointing. Malander correctly points out that it is far more rational to correct the trouble by determining whether it is in the alkalinity or in the working of the second filter presses that the fault lies.

**Influence of temperature.** — Without doubt, as previously pointed out, the temperature has a very important influence upon the exit flow from a filter press, and the same may be said of mechanical filters working under low pressure. The temperature plays an important rôle when syrups from the multiple effect are to be filtered. Brendel * in his experiments (Fig. 247) upon a syrup

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* Brendel's Experiments.

| | | | |
|---|---|---|---|
| +2.3° C. | there was a flow of | 3.1 | grams of solution. |
| 8.0° C. | " " " " " | 9.7 | " " " |
| 21.0° C. | " " " " " | 22.0 | " " " |
| 30.0° C. | " " " " " | 37.3 | " " " |
| 40.0° C. | " " " " " | 66.8 | " " " |
| 47.0° C. | " " " " " | 91.2 | " " " |
| 60.0° C. | " " " " " | 146.8 | " " " |

(Jahrb., **33**, 193, 1893.)

containing 60 per cent of sugar, noted the quantity of filtrate passing through the filtering cloths per minute as it leaves the evaporating appliance, and showed that at 60° C. there was 146.8 grams of syrup running off, while at 2.30° C. there was only 3.1 grams. This influence of temperature is made evident in the diagram (Fig. 247).

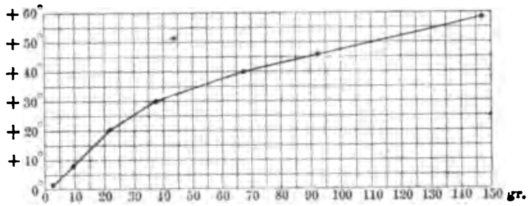


FIG. 247.—Diagram showing the Influence of Temperature upon the Exit Flow of Syrup.

Although it is very much less with diluted juices it still exists, and one may conclude that a satisfactory filtration can only be realized when the juices are as hot as possible.

**Pockets or bags.**—The substance used as a filtering medium in the mechanical filters is generally a thick, tightly woven cotton fabric. It should be sufficiently strong to withstand the wear and tear at the joint, and experience shows that there are important advantages to be derived by sewing on the border of the bags or pockets a linen band which acts as a joint. These bags must be well washed. In certain factories a 2 per cent solution of hydrochloric acid is used for the purpose in order to eliminate the lime deposited, in which case it is desirable to dip them in a sodic solution also. Fatty substances, used for arresting the froth in one of the previous operations of sugar extraction, are often deposited upon the filters, and under such circumstances advantages are to be derived by washing the bags in a 5 per cent sodic solution. For this purpose the apparatus used for the filtering cloths of a filter press may be employed. The operation should be conducted with great care, as neglect in this respect will influence all the operations that follow. Under no circumstances should scrubbing of the bags be permitted. The pockets may work for a week under ordinary conditions without being renewed.

**Size of filtering surface.**—All the mechanical filters of the pocket type have frames of the same size, 70x70 cm., which for the two filtering surfaces of the frame equals about 1 sq. m. The num-

ber of frames varies from 20 to 50 according to the kind of filter. The filtering surface necessary for the juice or syrup is most difficult to determine. It depends upon many circumstances, such as the nature of the filtering medium, the temperature of the juice or syrup being filtered and the pressure at which the operation is conducted.

**Sugar losses.**—As the first filtrate running from the syrup presses is cloudy it is sent back to the saturation tank to be again treated. The deposits upon the filtering cloths are very readily washed. However, presses intended for washing scums need not be used for syrups, and as the separated deposits contain considerable sugar they may be advantageously returned to the carbonatation tanks. It is very doubtful whether there is any real advantage in recovering the juice by soaking the filtering cloths, as diluted juice undergoes considerable change when allowed to stand for some time, and these changes are difficult to obviate. As a general thing, the sugar losses in the scums and the filtering cloths are so small that they may be ignored.

**Continuous filters.**—Efforts have been made from time to time to introduce a continuous filter. The BERNSTEIN * apparatus for beet juices consists of a rapidly revolving receptacle, the exterior border of which is raised higher than the inner part and is covered with a disk, allowing a free passage of the entrance pipe for the juices. The space between the interior border and the axis is covered by a perforated plate or some filtering material. The juice entering into the chamber thus made is submitted to the action of rotation. The solid particles held in suspension are projected towards the outer periphery of the apparatus and accumulated in the gutter. On the other hand, the juice freed from these substances passes through the filtering medium and collects in a receptacle beneath. It is possible by forcing the filtering medium to revolve to accomplish the same results, but it becomes necessary in such a case to place an agitator in the center of the apparatus. Besides this combination numerous others, having very much the same idea in view, have been in use, but none of them very long.

**Sand filters.**—The use of sand as a filtering medium was proposed by MEYER in 1879, and, as previously stated, it was the starting point of a reaction against boneblack. Notwithstanding the excellent results obtained with sand, both for juices of second carbonatation and for syrups, beet-sugar manufacturers hesitated for

* Z., 51, 533, 1901.

a long time to adopt it and while the use of sand or other substances consisting of granules in filters, like those used for boneblack or in special sand filters, is very satisfactory, it involves additional labor, as such filtering substances must be purified by repeated washings and frequently renewed, as compared with pocket filters.

The types of sand filters are very numerous, the most popular ones to-day being those of ABRAHAM and of BREITFELD and DANEK. The ABRAHAM (Fig. 248) filter consists of a receptacle containing

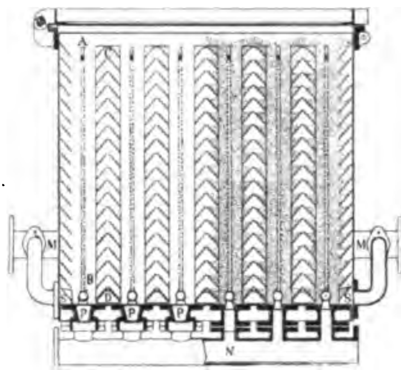

FIG. 248.—ABRAHAM Sand Filter.

six metallic frames *A* of very much the same arrangement as that used in the PHILIPPE filter, but upside down. These frames are covered with a fine wire cloth, never with one of fibrous material, and communicate at the bottom with the exit passage of the juice *N*. Between the six frames already mentioned are placed other frames *C*, which consist of long strips of sheet iron held together by a series of bent strips also of sheet iron and placed one over the other. In the ridged portion of the bend there is a slit of 5 mm. extending over its entire length. The sides of the receptacle also have slanting strips. The apparatus is filled with sand which falls naturally on the bent parts without clogging the slits. The receptacle is closed and the juice is introduced through *M* at the lower part of the frame *S*, *D*, etc. In its upward movement it escapes through the slits of the bent iron and then through the wire covering. During its passage through the sand a large part of the impurities is deposited, and upon reaching the interior of the frames it falls by gravity and escapes through *N*.

The ABRAHAM filter has undergone many modifications, one of the most recent being shown in Fig. 249. It consists of a large

vertical cylinder containing a series of bottomless plates, the interior of which is filled with sand. The syrup to be filtered enters the apparatus at $A$, passes through the sand into a central cylinder covered with a wire gauze and escapes through the bottom opening $B$. The sand may be removed from the filter through a bottom manhole, and after the apparatus has been thoroughly cleaned it is filled with fresh sand.

The REINECKEN filter (Fig. 250) works on very much the same principle as the new type of ABRAHAM filter just described; but

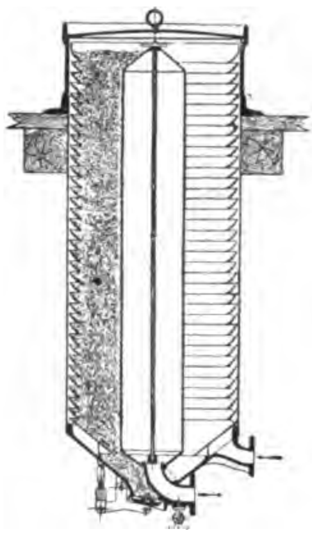

FIG. 249.—Recent ABRAHAM Filter.

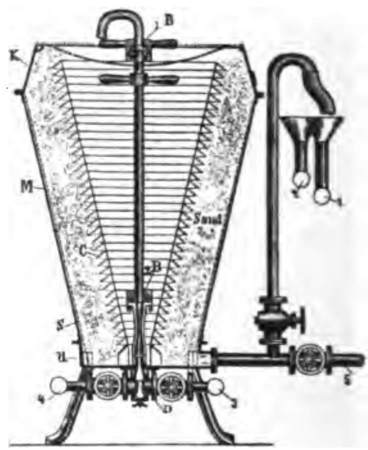


FIG. 250.—REINECKEN Sand Filter.

there is an important difference, in that the juice gradually penetrates through 3 from the bottom and is distributed through a central perforated pipe, not shown in the drawing; it then escapes through the conical cylinder $C$ into the sand and passes through the pipe 5 into 1 and 2. This flow from the interior to the exterior has many advantages, among which may be mentioned a constant decrease in its velocity, with the result that the particles in suspension which would otherwise have been carried forward are retained by the sand granules. To clean this filter another pipe $D$ is substituted for the central distributing pipe and an injector 2 and $B$ is used. Water introduced under considerable pressure carries the sand into the injector, which forces it upwards through $B$ and distributes it where needed. During this

movement the sand granules rub against one another and are freed of all their impurities.

In the Breitfeld and Danek filter (Fig. 251) the heated syrup or juice enters by the valve $V'$ through a distributing pipe $D$ into a large rectangular receptacle $A$ filled with sand up to the level of $D$. When the juice reaches a level of about 25 cm. above the surface of the filtering medium the valve $V'$ is regulated so that this level is maintained, and the juice or syrup after passing

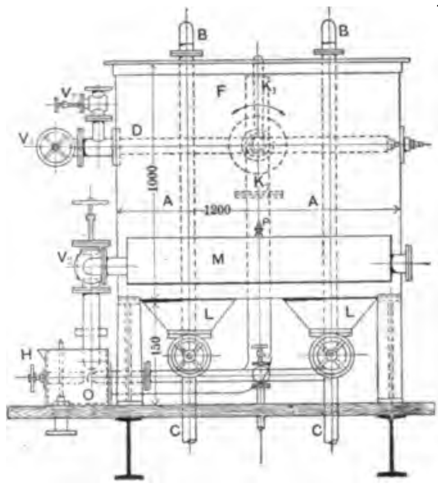


Fig. 251.—Breitfeld and Danek Sand Filter.

through the sand escapes by the valve $V^2$, which is fully opened only when the filtrate is limpid. To wash the sand the filter is first of all thoroughly rinsed with hot water introduced through the valve $V^3$, then water or steam is circulated from the bottom under considerable pressure and forced by the injector attachment through the pipes $CB$ into the sand, which is thus raised and cleaned through the friction of its particles, and is then forced upwards and returns to the receptacle at $B$. The washing of the sand is one of the delicate features of this apparatus, and if it is not properly done the filtration will be slow and very unsatisfactory, accompanied by numerous other complications, such as fermentation through the action of micro-organisms.

**Application of sand filters.**—Satisfactory results may be obtained even when filtering molasses at 40° Bé., provided, however, that it has been heated to 95° C. Sand filters are seldom

used for carbonatated juice, as they would soon be clogged with lime, but it has been proposed to use them* for juices being concentrated in the multiple effect. The filters are placed between the first and second compartments of the evaporating appliance, and have level and vacuum attachments; during the early stages of the operation the juice will pass through the lower strata of the filter. The vacuum gauge will give the difference in vacuo between the two compartments in communication, but as the sand becomes clogged the level of the juice in the filter gets higher, and when the filter becomes entirely full of juice the sand must be renewed.

**Kind of sand.**—The filtering substance used in these filters may be river sand that has been sifted and well washed, or any other granular substance. According to Breitfeld and Danek,† the sand used should be of a uniform size well sifted through a sieve with standard mesh. According to Abraham, the size of the sand granules giving the best results is 0.6 mm., although in certain filters the granules are nearly the size of a pea. This authority furthermore declares that the size of the sand granules and the rapidity with which the liquid circulates are the most important factors to be taken into consideration after the filtering area of the apparatus. The thickness of the layer of sand plays a secondary rôle but beyond 30 mm. its filtering power ceases, the active filtering strata being limited to from 10 to 20 mm. As to the rapidity of the flow of juice through the press the best results are obtained from a velocity corresponding to 2000 mm. per hour for non-concentrated juice, 600 mm. for concentrated juice and still less for after-products.

**Use of infusorial earth.**—Frequently, with the view to facilitate filtration, such substances are added to fresh juices as will attract very fine particles of scum, mainly such as tend readily to clog the filtering cloths. Wood-powder, cellulose and infusorial earth may give satisfaction. The use of infusorial earth has been recommended by Heddle, Glen and Stewart. The quantity used is about equal to one-half the sugar percentage of the juice or syrup, and the mixture is then sent to any kind of a filter. The thick syrup in a subsequent operation is treated in the same way.

When the substance becomes so clogged that it no longer serves as a filtering medium it is washed with water or steam and

* S. B., Dec. 1900. † S. I., **61**, 559, 1903.

completely regenerated by carbonization in char kilns. This infusorial earth is known in Germany as "Kieselguhr," and under that name it is frequently used in beet-sugar factories. SOXHLET* suggested filtering saccharine juices after mixing them with so-called wood-wool, infusorial earth, pulverized pumice stone, or washed coke and sending the filtrate through the SVOBODA pocket filters after its passage through the presses. At the ENSINGER † (Germany) factory the "Kieselguhr" undergoes a preliminary heating 120° C. with a 20 per cent hydrochloric and a 1 per cent nitric acid solution, and is subsequently worked in a centrifugal to rid it of the adhering liquid; it is then washed so as to eliminate the last trace of acid and pressed, being kept in parchment to prevent excessive drying. Before being used it is placed in water and this water with suspended particles is forced by a pump against the filtering cloths, where it deposits in layers and offers special filtering and sterilizing advantages.

Of late years RAGOT has also used this substance to facilitate the filtration of first carbonatation juices, using only the minimum quantity of lime. The difficulty found in the MEAUX (France) sugar factory is the cost of the regeneration of "Kieselguhr." However, in that factory the substance continues to be used with success for the filtration of syrup and after-products. The quantity giving the best results is 0.05 per cent, thoroughly mixed with the products before filtration. The after-products are then run through PHILIPPE filters and the syrups through filters very like filter presses. The regeneration of the infusorial earth necessitates a carbonization of all the organic substances covering the granules. The carbon acts like boneblack with a decolorizing effect. For this purpose it has been proposed to submit the "Kieselguhr" ‡ to the following treatment: It is heated to red heat, and into this incandescent mass, which contains no air, are injected heavy hydrocarbides. At the temperature to which they are exposed these will decompose and give a porous texture. Upon the surface of this filtering mass there will be a deposit of lampblack which exerts an intense epurating and decolorizing action upon the juice with which it subsequently comes in contact. To increase the adherence of the particles of carbon one may, after the preceding operation, saturate the mass with hydrocarbides and heat to red heat.

In selecting infusorial earth it must not be forgotten that

* Z., 43, 969, 1893. † Z., 51, 354, 1901. ‡ Z., 51, 489, 1901.

there are many kinds which do not give a colorless filtrate, and owing to the combination of alkali with silica certain precautions should be taken to avoid a decrease in the existing alkalinity, and, furthermore, silica under certain conditions may give a characteristic coloration to the juice. Of twelve samples examined by HERZFELD * only one was shown to be suited to the intended purpose, as it gave a perfectly colorless filtrate. The alkalinity of the juice fell through its action from 0.15 to 0.0005 per cent. This last property is possibly due to the formation of a double silicate of lime and alkali.

**Filtration through wood** arranged as a series of small obstructors, or in various forms of wood-wool,† etc., may in certain cases also be recommended. It is now nearly twenty years since CASSAMAJOR,‡ then chief chemist in a large Brooklyn refinery, invited the writer to see some experiments he was making which had for their object the elimination of filtering cloths in filter presses, by using wood shavings or sawdust. Since then the plan has assumed a practical shape and is in operation in several German factories. The filtering medium is a fibre obtained by chopping wood into fine particles through which were successfully filtered the first swing-out syrups which had undergone a previous sulphuring. The filtrates were white and their general color was not inferior to that obtained by the use of boneblack. It is important to note that this vegetable fibre has also been used for carbonatated juices, and for concentrated syrups from multiple effects. The results obtained were a pronounced success.

The wood-filtering medium need be renewed but twice during a sugar campaign, a bi-weekly washing with diluted hydrochloric acid alone being sufficient to keep the product in a good condition. As water is run through the filters previous to their acid washing the sugar loss is very slight. The cost of keeping these filters in good working order is but a few dollars and they need no watching. The leading experts recommend that the filtering medium be submitted to a preliminary sodic treatment which will eliminate the acids. The advantage of very fine chopping of the wood is the assurance that it will pack well in the filter, and in this manner offer advantages never realized when using

* Z., **46**, 745, 1896.

† Wood-wool is a special preparation of wood.

‡ Am. patent No. 270,634; La. S. B., **16**, 514, 1888; Sugar Cane, **20**, 372, 1888.

horsehair, as is done in several instances coming under our notice. Experience shows that under no circumstances should a resinous wood be used for these filtrations.

Dr. HERZFELD * has for some time been making experiments with pulverized wood and also with wood fibre as filtering materials. Saccharine juices of 0.1 per cent alkalinity lost this alkaline condition when filtered at a boiling temperature through wood fibre. He also recommends that the product be chemically prepared before being used, a precaution too frequently neglected, and as a result pectic and resinous substances are introduced which offer great difficulties in graining syrups in pan, and certain objectionable ferments are also found in the juices.

STENZEL,† who has looked into the question of wood-wool filtration, also urges that it be washed in a boiling 0.2 per cent solution of caustic soda. The water used for the subsequent washing may be from the condensors. The steeping lasts one-half hour; then there is another steeping in the soda solution, which is followed by washing until the water runs off clear. The filters are first filled with the wood-wool and then with the juice to be filtered. Experience shows that this filtering medium may last for an entire sugar campaign.

**Cellulose as a filtering medium.**—Among the variations of the wood-wool filtrations may be mentioned the use of cellulose obtained from fibrous materials Paper fibre ‡ as a filtering medium is a recent innovation. Very thin paper is used for the purpose; it is run through a special apparatus and comes out as a long fibre without knots. It is forced into beet juices and deposited on the frames of the filter presses where it forms a layer which acts as a filtering medium.

**Cork as a filtering medium.**—Good results are said to have been obtained by allowing small particles of cork to float on the top portion of the filters with which the juice comes in contact in passing from bottom to top. WAGNER § recommends that juice be filtered through a layer of chopped cork held in position between the sieves in a cylinder, the liquid passing through the cork from top to bottom. The cork should be washed every few days and be submitted to a weekly steeping in dilute hydrochloric acid which will dissolve the calcareous deposits.

* Z., **46**, 92, 1896.
† D. Z. I., **25**, 1121, 1900.
‡ D. Z. I., **26**, 1214, 1901.
§ Jahrb., **33**, 162, 1893.

Excellent results continue to be obtained by the system of filtration of thick juices over rasped cork. For holding the cork the old bone filters may be used, it being necessary, however, to have at top and bottom a wire cloth acting as a sieve. The filtration should be from bottom to top, and the pressure on top should not be more than 2 meters. The height of the filter depends upon the work to be done, the higher it is the more perfect the filtration. The cork will give satisfactory results for three weeks, but a washing with hot water is found necessary every few days. After having been used for the time mentioned, the cork is thoroughly washed and dried, and may be again used. A filter 5 meters high, containing say 600 corks, is sufficiently large for a factory working 150 tons of beets a day. The expense is about one-quarter of a cent per ton of beets worked.

**Other filtering substances.** — Numerous other filtering substances have been suggested, among which may be mentioned peat, pulverized lignite, as suggested by KLEEMANN,* and asbestos. Asbestos † has given very satisfactory results in the filtration of syrups and beet juices. It is said that a perfect clarification is obtained by its use. In nearly every existing system of filtration the first juices or syrups leaving the apparatus have a cloudy appearance; such is not the case with asbestos, as the filtered juice or syrup is perfectly limpid from the start. One great advantage of using this product is, that when covered with lime deposits, etc., these may be eliminated by a weak solution of hydrochloric acid, which does not attack the asbestos, but simply combines with the lime. While asbestos ‡ gives satisfactory results experience has shown that the wear and tear on the material is very great. The cleaning of these filters is a still further loss, and the cost has consequently compelled many manufacturers to abandon the process.

**Filters with fibrous substances.**—Besides the appliances already mentioned there are numerous other ones, such as the BOUVIER (Fig. 252), which consists of a horizontal receptacle containing several layers of filtering substance pressed between the plates *bb*. Between the different layers are fixed iron disks *a*, which force the juice to circulate in a zig-zag direction through the filtering medium beneath. The deposits on the obstructors fall into a trough and may be occasionally removed at *P*. Before leaving the apparatus the juice runs through a layer of horsehair, *c*, which retains the last particles in suspension and then escape at *R*.

* Jahrb., 24, 418, 1884. † S. B., Nov. 1894. ‡ S. B. Sept. 1895.

Another excellent filter is the NAPRAVIL (Fig. 253). It consists of a rectangular receptacle *B* holding the filtering substance between two perforated plates *a* and *b*. The juice to be filtered enters the apparatus at *A*, is heated by coming in contact with the steam coil *S*, and rises through the filtering cloths *i*, stretched on wooden frames in the upper part of the apparatus. The juice thus filtered runs off through the overflow *p*. The PERRET * sponge

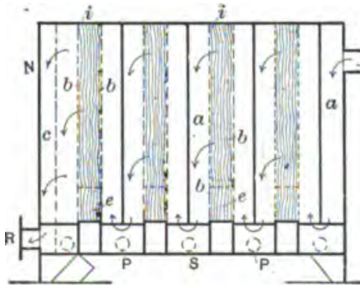


FIG. 252.—BOUVIER Fibrous Filter.

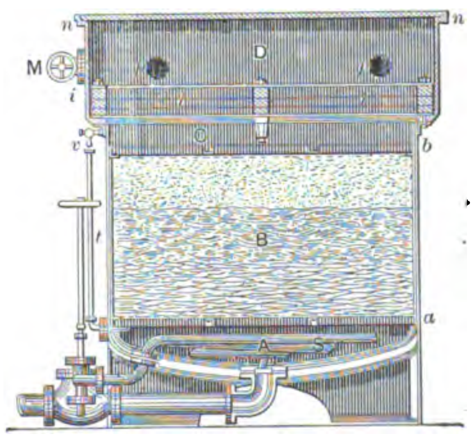


FIG. 253.—NAPRAVIL Filter.

filter is a trough of no special length, in which are placed frames, more or less tightened, which hold bundles of cotton threads. The juice enters at one extremity of the trough and leaves at the other after having left the impurities in suspension on the cotton fibre. Some claim that several chemical transformations follow which result in a chemical epuration due to molecular attraction, endosmose, etc.

* S. I., 21, 472, 1883.

## CHAPTER VII.

### SULPHURING OF JUICES AND SYRUPS.

**General remarks.**—For several decades the epuration of beet juices was limited to the action of such agents as lime and carbonic acid. It was known that sulphurous acid in some form had a more powerful decolorizing effect than boneblack, but although it has been in use for many years its advantages and disadvantages in beet-sugar manufacturing processes are still under discussion. There are practical difficulties in the way of its use, and its decolorizing and possible epurating properties, its influence upon viscosity and its inverting powers have been the cause of numerous controversies. The antiseptic properties of sulphurous acid and its influence upon the aspect and conservation of raw sugars are among some of the issues that it is interesting to examine.

It is to be noted that the concentrated juice or syrup in a multiple effect has a yellow or brown color and is cloudy on account of the precipitates formed during the evaporation. Its alkalinity depends upon the alkalinity and the nature of the juice before its concentration. The retrogression of the alkalinity during evaporation increases with the percentage of ammonia, albuminoids, invert-sugar, lime salts, etc., contained in the fresh juices. If there is no retrogression a concentrated juice or syrup at 60° Brix should have an alkalinity five times greater than a juice at 12° Brix. As a general thing, however, the alkalinity of these syrups is only three or four times greater than that of the non-concentrated juice, showing that the remainder has volatilized in the form of ammonia, or has been neutralized by the alkalies having combined, through a double decomposition, with the products of decomposition of the nitric substances, invert-sugar or calcic salts. The coloration of these syrups is darker than it should be. When the concentrated juice is diluted with water

so as to obtain the same density as the non-concentrated juice it is darker in color than it was when fresh from the carbonatation. All this shows the importance of a thorough decoloration of the juice.

Without doubt sand filtration and other innovations of a like kind have been largely instrumental in the strides made in sulphuring in beet-sugar manufacture. It is well to keep in mind several well-known facts relating to this decolorizing agent, the most important of which are its decolorizing, epurating properties, its influence on the viscosity of the saccharine solution, its inverting powers, its influence upon color and keeping powers of raw sugar, and last, but not the least, its antiseptic properties.

**Historical.**—DRAPIEZ * was the first to propose the use of sulphurous acid in the process of sugar extraction. He concentrated the raw juice to about one-half its original volume, added a mixture of lime carbonate and powdered charcoal, and after filtering and cooling the juice was sulphured. On the other hand, DUBRUNFAUT † brought sulphurous acid in contact with beet pulps, submitted the juice to a defecation in accordance with the old modes, and then neutralized the excess of lime by sulphuric acid. He admitted, however, that instead of that acid, sulphurous acid might be advantageously used. In this case there need be no hesitation in pushing the operation to the limit of an acid reaction.

The STOLLE ‡ patent was issued in 1838 upon the basis that sulphurous acid would act as a decolorizing substitute for bone-black. The juices were worked directly in the vacuum pan with a water solution of sulphurous acid which did not contain more than 1 or 1.25 per cent of sulphurous acid or sulphurous-acid gas. The juices are to be defecated with 1 to 2 per cent of lime, and when boiling the scum is taken away, and 12 pounds of liquid sulphurous acid (marking no more than 4° by BAUMÉ's areometer) are slowly and carefully poured into 1000 parts of juice. The juice is then evaporated to about 20° or 22°, passed through a filter of flannel, etc., and concentrated to crystallization. With the exception of the defecation, for which combined carbonatation and defecation has been substituted, the STOLLE mode is in nearly every respect the same as one in use to-day for the sulphuring

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* Bull. Sté d'Encouragement de Paris, **10**, 56, 1811

† Br. Français, 2543, 1829.

‡ Sugar Specifications, No. 7573, 1838.

of saccharine juices. Another method is used with syrups rather than diluted juices, and in this bears a striking resemblance to the DRAPIEZ process.

In STOLLE's French patent of a more recent date mention is made of the use of gaseous sulphurous acid as a decolorizing agent. It is astonishing that fifty years elapsed before this chemical came into general use in the manufacture of beet-sugar, notwithstanding the fact that numerous experiments were made during the interval. MELSENS,* for example, attempted to substitute for sulphurous acid its calcic salt, the bisulphite of calcium, but its use was confined mainly to cane-sugar extraction. Sulphuring came generally into vogue in 1869 through the SEYFERTH patent,† in which was proposed the sulphuring of the *massecuite* while graining. During this concentration the sulphurous acid was completely eliminated and the beet flavor was no longer perceptible in the resulting sugar. During this operation the sulphurous acid as well as the volatile organic acids were, according to the inventor, carried out by the watery vapor, and the sulphurous acid consequently acted as an important epurating agent. Numerous investigations have from time to time been made with certain variations on this idea.

**The action of sulphurous acid upon coloring substances** is most varied. BASSET ‡ went so far as to doubt the stability of the decolorizing efficacy of the gas, and maintained that the coloring substances acted upon were not destroyed, as the original color reappeared if the acid were neutralized. Regarding this theory, it must be remembered that whatever be the degree of neutralization the original color is not entirely restored. Therefore, it is reasonable to admit that sulphurous acid destroys at least a portion of the coloring substances contained in saccharine juices, forming certain other combinations which may have somewhat the same hue though in a much less pronounced degree, but even this is not stable. If, on the other hand, the sulphurous acid is brought in contact with lime, for example, the coloring substance of the combination with its original color will reappear. Argue as one may, sulphurous acid destroys only a portion of the coloring matter, and its use must be limited accordingly.

* Dingler's Polyt. Journ., **113**, 393, 1849

† Sugar Specifications, No. 7256, 1869.

‡ Basset, Guide, **2**, 750, 1872.

FRADISS * in an important monograph declares that sulphurous acid will bring about an important decoloration of caramel, especially in a medium rendered acid through the action of the decolorizing agent under consideration. Other authorities seem to doubt the accuracy of the experiments in question, and maintain that there has been confusion between caramel and some other coloring substance. According to SCHULZE † the accepted theory that sulphurous acid destroys the coloring substance by the removal of the oxygen is not based upon sufficiently accurate data to be generally accepted.

There is evidently a certain relation between the quantity of sulphurous acid used and the ultimate decolorizing effect obtained. Many experts maintain that the action of this chemical upon saccharine juices is due solely to its acidity. The BATTUT ‡ experiments with hydrochloric and sulphuric acids led to a discoloration about 50 per cent less than with sulphurous acid; hence it is reasonable to suppose that the latter agent effects certain chemical transformations that are entirely independent of the acidity of the product. Some attempts have been made to combine air with the sulphurous acid, but it is not clear what advantages are to be gained.

**Epurating role of sulphurous anhydride.**—From what has been said in the foregoing, there seems to be no doubt but that sulphurous acid produces an important epurating effect upon raw-beet juices drawn from the diffusion battery, and when the sulphuring is properly conducted the epurating effect is about the same as that obtained through double carbonatation. Unfortunately, however, these fresh juices when sulphured are very difficult to filter and the impurities in suspension cannot be readily separated by existing filter presses. This explains why this mode of epuration is not used during one of the early phases of sugar extraction.

It would be interesting to know whether there is obtained an actual epuration by existing processes in which the sulphuring follows the defecation carbonatation, but upon this subject the authorities differ. VIVIEN and MESSIAN § declare that there can be no doubt of the epurating action, while FRADISS'S ‖ experiments in sulphuring syrups lead to the belief that there follows a considerable elimination of organic substances. On the other hand, AULARD ¶

* Bull. Syd., **27**, suppl. p. 9, 1899.
† Z., **21**, 72, 1871.
‡ Bull. Ass., 8, 210, 1890.
§ S. I., 28, 261, 1885.
‖ Bull. Synd., **27**, suppl., p. 16, 1899.
¶ Bull. Synd., **27**, p. 75, 1899.

claims that the fatty substances added to juices are eliminated during sulphuring as insoluble calcareous soaps. In the absence of an actual epuration, the propriety of considerably modifying the organic substances of the juices is attributed to sulphurouss acid. SCHEIBLER * thought that possibly sulpho-conjugated acid were formed between the sulphurous acid and the organic substances. But the experiments of SCHULZE † demonstrated beyond cavil that sulphurous acid does not form combinations with organic acids resulting in the formation of sulphonic acids. According to FRUEHLING and SCHULZ ‡ sulphurous acid has no specific epurating action. They claim that by submitting beet-juices under like conditions to the action of either carbonic or sulphurous acids identical epurating effects are ultimately obtained, and PELLET entertains very much the same views. The argument of BATTUT on the same lines is that as there is no precipitation in a juice made up of *massecuite* dissolved in water, the action of sulphurous acid is upon the nitrogenous and coloring substances of raw-beet juices, but that these are entirely eliminated during double carbonatation, and that there can consequently be no elimination of the proteids, etc., in the syrups, *massecuites*, etc.

According to AULARD § the sulphuring has little or no influence upon the purity of syrups, but there are other important advantages, as shown by the facility with which a syrup will crystallize after the sulphurous acid treatment. It is maintained that an important action upon the organic calcic salts has taken place. As regards the action of sulphurous acid upon the saline elements contained in beet juices and syrups the authorities are no nearer an understanding than they are as to the foregoing. Without doubt sulphurous acid will saturate the lime and free alkalies and will precipitate the lime from its organic combinations. The principal controversy relates to the solubility of sulphite of lime in beet juices; it is generally claimed that it is more soluble than the calcic carbonate. During evaporation a part of the former is separated, provided the juices have been sulphured before entering the multiple effect. An important fact not to be overlooked is that sulphurous acid decomposes the organic lime salts while carbonic acid has no such action. Under these conditions a certain percentage of the lime salts is necessarily eliminated when the sulphuring continues until reaching an acid

* Z., 20, 468, 1870.
† Z., 21, 74, 1871.
‡ Bull. Ass., 2, 273, 1884.
§ La. S. B., 18, 3, 1889.

reaction. DEGENER * consequently was perfectly correct in his assertion that sulphurous acid will precipitate lime more readily than carbonic acid. That more lime remains in solution after sulphuring than in the case of carbonatation, would not alone be a sufficient reason for giving unconditional endorsement to the use of sulphurous acid as an epurating agent.

According to AULARD † the alkaline carbonates are more greedy for water and more melassigenic than the sulphites, and this fact is an additional argument in favor of sulphuring. ECKLEBEN ‡ maintains that the quantity of sulphite of lime remaining in saccharine solutions varies with the amount of sulphite formed during sulphuring. It was shown by his experiments that for 10 per cent sugar solutions, corresponding to juices of second carbonatation, there was 0.016 to 0.034 per cent, while for syrups the sulphite of lime percentage varied from 0.028 to 0.029. He recommends that the sulphuring be continued until the juice treated is neutral, as shown by the phenolphthalein test, which would show that all the lime has been transformed into a neutral sulphite of lime. It is under these conditions that the juice retains the smallest percentage of sulphite.

Many authorities point out that one of the most objectionable features of sulphuring is that there is always danger of a sulphate being formed, the effect of which would be to decrease the quality of the ultimate sugar extracted. Although numerous experiments have been made demonstrating that these views have no practical foundation, the question has again been discussed by some of the leading experts. WENDELER § maintains that an appreciable quantity of sulphate is formed during the processes of manufacture following the sulphurous acid treatment, and he also noticed a higher percentage of sulphuric acid in the sugar extracted, a consequence of the sulphuring. On the other hand, 150 sugar analyses made in von LIPPMANN'S ‖ laboratory showed that such juices contained a smaller percentage of sulphates than those which had not been sulphured. This was before the operation had been generally introduced into beet-sugar factories.

**Influence upon viscosity.**—It has always been impossible to observe the slightest difference in the viscosity of sulphured and unsulphured syrups. BATTUT ¶ pointed out the truth of this assertion

* D. Z. I., **2**, 1228, 1887.
† Bull. Synd., **27**, suppl., p. 73, 1899.
‡ Z., **40**, 814, 1890; Z., **40**, 816, 1890.
§ D. Z. I., **28**, 15, 14, 1903.
‖ Z., **33**, 631, 1883.
¶ Bull. Ass., **8**, 215, 1890.

and, as already stated, great advantages result from this treatment as regards the rapidity and facility of graining and crystallizing, as shown even in the case of two syrups of the same alkalinity and purity, one of which has been sulphured and the other not. To what may these advantages be attributed? HORSIN-DÉON * declares that sulphured juices may be more readily concentrated in a multiple effect than those which have been carbonatated, for the reason that the specific heat of the sulphites is less than that of the carbonates. Furthermore, he maintains that the viscosity that is measured with a viscosimeter may not be the only kind that exists, and that there may be a latent viscosity which cannot be estimated by any known instrument. Among the strange contradictions in the realm of this entire subject may be mentioned the observations of BATTUT † which lead one to believe that notwithstanding the fact that sulphured syrups crystallize, etc., more readily than the non-sulphured, the amount of sugar obtained from the *massecuites* in the two cases remains about the same.

**Action upon sugar.**—No bias was more difficult to overcome than the belief that sulphurous acid had an inverting effect, the inversion being mainly due to the formation of sulphuric acid and then sulphates in the syrups, which increased the percentage of mineral substances in the sugar. SIDERSKY ‡ considers it a mistake to continue the sulphuring to acidity, for there would then be danger of inversion, and, furthermore, the same decolorizing effect may be attained by keeping the syrups alkaline. BATTUT § also noticed an inversion of juices which had been made acid by sulphuring, especially in such as were kept for hours at a comparatively high temperature, but these conditions are not realized in practice. BEAUDET ‖ says that the destructive action of sulphurous acid upon pure sugars is very slow under 50° C. and that it is perceptible only after a temperature of 55° C. is reached, and from that temperature upward it is very pronounced. It is to be noted that the alkalinity of the syrups being treated plays a very important rôle, and that the acidity cannot evidence itself so long as the alkalinity is not done away with. In a pure sugar solution that has been rendered acid through sulphuring, this acid, which is only moderately

* HORSIN-DÉON, Acide sulfureux, p. 7, 1899.

† Bull. Ass., 8, 217, 1890.

‡ Bull. Synd., 27, suppl., p. 63, 1899.

§ Bull. Ass., 8, 194, 1890.

‖ Bull. Synd., 27, suppl., p. 313, 1899.

powerful, according to another authority, will bring about an inversion at a comparatively low temperature. In an impure solution the conditions are no longer the same. The sulphurous acid will combine with the base of the organic acids, which are weaker than it is and have less inverting power. The sulphurous acid being combined as a sulphite is not so active. In an acid solution the weaker acids are always liberated first, which explains why a moderate acidity is always followed by a but very slight inversion.

SPOHR * had already noticed that the presence of certain organic salts exerted a depressing action on the inverting power of organic acids; for example, acetic acid loses 97 per cent of its inverting power in the presence of potassium acetate. BODENBENDER and BERENDES † made experiments to determine the inverting action of sulphurous acid, and noticed that it was greater and more rapid if brought when hot in contact with pure sugar solutions. Very little sulphuric acid is then formed, and consequently its inverting action must necessarily be excessively small. The inversion was even less in the presence of alkaline salts of organic acids and almost zero in the presence of alkaline carbonates. BATTUT ‡ in his numerous experiments at temperatures reaching 80° C. upon syrups and after products of sugar factories, never noticed the slightest inversion even when neutrality was exceeded. GRUNDMANN § did not hesitate to continue the sulphuring until reaching an acid reaction at 75° to 80° C. The syrups were subsequently rendered alkaline, which condition was reduced with sulphurous acid. After the addition of lime the juice becomes very dark in color, but it is very much clearer than through the regular sulphuring.

According to AULARD ‖ there need be no apprehension as to acidity with syrups of a low purity. SIDERSKY ¶ claims that when sulphuring syrups there is very much less danger of inversion than with diluted juices, and that the change, furthermore, is much slower. URBOUIN'S ** experiments lead one to conclude that the oxidation caused by the ambient air must play an important rôle during sulphuring, causing an inversion, and that even when ex-

* C., **5**, 938*a*, 1897.

† Z., **23**, 21, 1873.

‡ Bull. Ass., 8, 191, 1890.

§ D. Z. I., **16**, 30, 1891.

‖ Bull. Synd., **27**, p. 75, 1899.

¶ Bull. Synd., **27**, suppl., p. 42, 1899.

** Bull. Ass., **15**, 98, 1897; Bull. Ass., **15**, 103, 1897.

posed to the air without sulphuring there is a perceptible inversion at 60° C., while under vacuo it commences only at 86° C. These experiments were conducted with pure sugar solutions. When handling regular juices from the carbonatation tank these temperatures are somewhat higher—85°C. in the air and 90° C. under vacuo. Evidently when sulphurous acid comes in contact with the atmosphere it is changed into sulphuric acid, which necessarily inverts a portion of the sugar with which it comes in contact. This principle, however, has been contested by BATTUT,* who claims that sulphurous anhydride mixed with air exerts no inverting tendency upon the sugar in juices. The fact is that in many German beet-sugar factories air and sulphurous acid are combined during sulphuring, and it seems doubtful that the mode would continue in use if it caused sugar losses.

**Influence upon the aspect and keeping qualities of sugars.**—Numerous experts have repeatedly claimed that the sugar obtained in factories where sulphuring was practised during several phases of the extraction was of an inferior aspect and quality with a characteristic bad odor. This was the outcome of sulphuric acid having been formed, which in some cases was transformed into sulphuretted hydrogen or even into sulphur. BODENBENDER,† on the other hand, could never find the slightest indication of inversion. LIPPMANN ‡ points out that one of the essentials to assure the keeping power of sugars is that they have sufficient alkalinity. This would apply to sugars in general. WENDELER'S § observations during a period of nine months led to the conclusions that sugars from juices, syrups, etc., which had been sulphured, had darkened more than those from the non-sulphured products; but, on the other hand, as the sulphured sugar was brighter at the start the final hue was decidedly in favor of the sugars from sulphured juices.

**Antiseptic properties of sulphurous anhydride.**—The antiseptic properties of sulphurous anhydride are open to considerable discussion, and it too frequently happens that the arguments relating thereto are very much exaggerated and not based upon facts. BATTUT'S || experiments show that sulphured juices with some alkalinity have greater keeping powers than carbonatated juices. On the other hand, it is to be noticed that the antiseptic

* Bull. Ass., 8, 191, 1890.
† Z., 34, 559, 1884.
‡ Z., 33, 631, 1883.
§ D. Z. I., 28, 1516, 1903.
|| Bull. Ass., 8, 185, 1890.

properties of sulphurous acid are not lasting when considerep from the standpoint of the after products, as after 15 to 20 days all the sulphurous acid will have been changed into sulphates * upon coming in contact with the organic substances contained in the *massecuite*. Upon general principles, it may be admitted that if the *massecuites* remain alkaline they have about the same tendency to ferment whether they have been sulphured or not; on the other hand, if they contain free sulphurous acid they may be kept for a long time without the slightest fermentation.

From what has been said it would appear that sulphurous acid has no epurating effect upon juices, or only a very slight one; that it gives no increase in the final yield of sugar; that it is a powerful decolorizing agent; that it facilitates the graining and crystallizing in pan, and that it contributes in a certain degree to the keeping qualities of sugar.

**Most desirable time for sulphuring.** The sulphuring may be effected during different phases of sugar extraction: (1) upon diffusion juices; (2) after first carbonatation; (3) simultaneously with second carbonatation; (4) after second carbonatation; (5) after partial evaporation, upon syrups that are not entirely concentrated; (6) upon syrups after leaving multiple effect, and (7) upon after products.

The sulphuring of diffusion juices is seldom practised. The main discussion is as to whether the sulphuring should be applied to diluted or concentrated juices or syrups. When non-concentrated juices are sulphured to neutrality one obtains beyond cavil a cleaner juice than the alkaline ones; however, the ultimate color cannot be taken as a basis for the treatment of the juices, as it undergoes serious modification during the various operations of sugar extraction which follow. The sulphurous acid then has a longer time to act and may bring about an important decolorizing effect; but unfortunately, this is not lasting. WEGE † recommends that the operation be upon the juices of first and second carbonatation so that the action may be more pronounced.

Without attempting to discuss the question as to whether concentrated juices should be slightly or excessively sulphured, one should endeavor to determine whether the last portions of lime are more advantageously precipitated in the fresh or concentrated juice in the form of a carbonate or sulphite of lime. To this end

* Bull. Ass., 8, 222, 1890. † S. I., 88, 1889.

the question of the solubility of these substances in a saccharine solution must decide, as a saturation of diluted juice, if pushed to an extreme limit, would not offer any special advantage unless the lime salts were less soluble in dilute than in concentrated juices. But nearly all the partially soluble calcic salts are less soluble in concentrated than they are in diluted sugar solutions, and during evaporation there are always deposited sulphate, carbonate and other salts of lime, upon the pipes of the evaporation appliance, whether the juices be alkaline or neutral.

BATTUT* noticed that sulphite of lime is six times more soluble than the carbonate in a 10 per cent sugar solution and eleven times more soluble in a 30 per cent solution. As its solubility is about the same in concentrated as in weak solutions it follows that by evaporating a 10 to 40 per cent solution three-quarters of the lime sulphite are precipitated. It consequently follows that sulphured juices always tend to form deposits on the heating surfaces of the multiple effect. The quantity of this deposit varies with the method of working. The desire to know the exact nature of these deposits and the best way of preventing them has led to many experiments and observations. BATTUT † says that 0.2 to 0.3 mm. of these deposits is sufficient to reduce by 25 per cent the heat transmission of a multiple effect. AULARD ‡ maintains that the deposits may be considerably reduced by allowing the lime to act upon the juices during their concentration; that the nitric organic substances will be decomposed, and that the sulphuring should fall after the juices leave the evaporating appliance. The sulphuring in this case being conducted under special conditions the syrups should be first run through mechanical filters; by taking this precaution the portions in suspension are not redissolved. HORSIN-DÉON § recommends that the concentrated syrups be sulphured rather than the carbonatated juices, and that the chemical be used upon raw juices from the battery in preference to all other modes of sulphuring, especially when handling inferior juices.

Among the changes that occur during evaporation may be mentioned frequent caramelization. FRADISS ‖ advances the rather

* Bull. Ass., 8, 227, 1890.
† Ibid., 226, 1890.
‡ Bull. Synd., **27**, suppl., p. 73, 1899; La S. B., **18**, 5, 1889.
§ HORSIN-DEON, Acide sulphureux, p. 13, 1899.
‖ Bull. Synd., **27**, p. 91, 1899.

original theory that the caramel in question is decolorized when brought in contact with the vapors of sulphurous acid. In some beet-sugar factories sulphuring is accomplished in the multiple effect by forcing sulphurous acid through the boiling juice, but as this system of saturation cannot be kept under control it is not to be recommended. There is no standard that can be established for concentrated juices upon attaining which one may be certain that they can be readily grained and worked in the operations that follow.

**Manner of sulphuring.**—The question of the best mode of sulphuring continues to be discussed. PRELLE * says that the operation may be conducted upon any carbonatated juice or syrup, local conditions deciding the question. He recommends that the first sulphuring be upon diffusion juices, this operation to be followed by a carbonatation, and claims that the results thus obtained are far better than those given by double carbonatation in the presence of 3 per cent of lime. Notwithstanding these assertions such methods have now become obsolete.

DE GROBERT † proposed to sulphur the alkaline juices of the last carbonatation which had been properly filtered, having 0.052 per cent alkalinity, and to lower their alkalinity to the neutral point. In order that the neutrality might be properly determined he makes the tests successively with solutions of phenolphthalein and methyl orange. The first decolorizes as soon as there is a bi-sulphite formation, and the second only when all the bases of the juice are transformed into bi-sulphites and in case free sulphurous acid already exists. In some factories it is customary to begin the sulphuring as soon as the juices leave the second carbonatation tank. VIVIEN ‡ recommends that the sulphuring be done in the tank, when the alkalinity has fallen from 0.01 to 0.02 per cent. This authority claims that the operation may also be satisfactorily accomplished upon syrups leaving the multiple effect. A rather original mode suggested by KRUEGER § consists in a simultaneous sulphuring and carbonatation upon first carbonatation juices. Upon general principles, such modes are not to be recommended, for there is always danger of a certain amount of the carbonate of lime being redissolved.

* Z., **39**, 670, 1889; S. I., **24**, 17, 1884; S. I., **24**, 45, 1884.

† Bull. Ass., **14**, 962, 1897.

‡ S. I., **30**, 679, 1887.

§ Z., **35**, 170, 1885.

By the best methods of working the sulphured juices or syrups are filtered before and after the sulphurous acid treatment. In certain factories visited by the writer, it was customary to sulphur the juices of second carbonatation and the syrup as it leaves the last compartment, or the last but one, of the multiple effect. HORSIN-DÉON calls attention to the fact that syrups from juices which have been sulphured generally have a low alkalinity or are neutral, and the operation of sulphuring can only be accomplished provided they undergo a special treatment. An addition of a small quantity of lime to the syrup overcomes the difficulty. The alkalinity then rises to 0.04 or 0.05 per cent and this is reduced through the action of sulphurous acid. According to SIDERSKY * sulphuring in the presence of lime is more efficacious than the acid method. In the latter case the results obtained are misleading, as there is recoloration due to neutralization. HORSIN-DÉON recommends that the sulphuring be done on syrup at from 12° to 18° Bé., and also that the operation be conducted upon the partly concentrated juices from the third compartment of a quadruple effect. The syrups to be sulphured should have a natural alkalinity upon leaving the multiple effect. It is insisted upon that it is a great mistake to attempt to sulphur neutral or acid syrups.

STEFFEN and DRUCKER † sulphur cool syrups or juices at temperatures below 60° C. until they are decidedly acid, and then submit them to the action of a small quantity of boneblack, finally neutralizing with lime. This new process ‡ for the epuration of saccharine juices by the use of sulphurous acid and boneblack has given some excellent results. The juice must undergo a first carbonatation followed by filtration to separate the scums and then be left to cool to about 38° C. Sulphurous acid is brought in contact with the juice until there is a characteristic acidity; at this temperature the sulphurous acid has no effect on the sugar. The juice after this treatment is filtered on boneblack, 500 grams being sufficient for 24 liters of juice. This filtration should be effected within the limits of 35° and 38° C. Lime is used to eliminate the acid in excess and thoroughly heating facilitates the formation of the insoluble salt, while filtration in special presses separates all the particles in suspension. The filtrate is slightly alkaline

* Bull. Synd., **27**, suppl., p. 53, 1899.
† Z., **44**, 999, 1894.
‡ S. B., July, 1896.

and almost colorless. It is claimed that even the raw sugar obtained from those *massecuites*, is almost white, and the residuum molasses of a light color. The sulphurous acid may be applied to syrups of considerable concentration instead of to juices, as mentioned above. This method was considerably in vogue and for some reason dropped suddenly into disuse. The fact that it * could not be patented in Germany may have been the cause.

**Alkalinity limit.**—In many factories it is customary to lower the alkalinity almost to neutrality, while in other cases it is contended that the only rational alkalinity is one of 0.03 to 0.04 per cent. The most reasonable plan is to establish the alkalinity in accordance with previous observations made during the working of the juice. If there is a considerable fall in the alkalinity during graining in pan that of the concentrated juice should be kept sufficiently high so that the *massecuites*, and consequently the first grade and the after product, will give a distinctive coloration with phenolphthalein. If, on the other hand, the concentrated juice contains considerable free alkali and no calcic salts, it may be saturated until it becomes nearly neutral, for the reason that in such juice a retrogression of alkalinity is not to be feared.

Difficulties are frequently attributed to an excessive alkalinity of a concentrated juice, such as being difficult to grain in pan and yielding sugar containing considerable ash, which are not due to that cause. The graining of concentrated juice is retarded only when the alkalinity is due to quicklime, that is to say when it contains a saccharate of lime. However, such is not the case with an alkalinity of 0.03 to 0.05 per cent, and the difficulty is more likely to have been caused by alkaline carbonate, caustic alkalies, or ammonia and organic bases. For the same reason an appreciable increase in the ash percentage cannot be due to the alkalinity. Under the most favorable circumstances the carbonates or alkaline sulphides that are formed by saturation with carbonic or sulphurous acids could enter into a double decomposition with the calcic salts by precipitating corresponding amounts of carbonate and sulphite of lime. Under these circumstances there would be precipitated a maximum of 0.03 to 0.05 grams of lime for 100 grams of concentrated juice, which contains 2 grams of ash or about 1.5 to 2 per cent of the total, or in other words, a fraction so small that it is not perceptible in the sugar.

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* Z., 49, 864, 1899.

As a double decomposition of carbonates and alkaline sulphides with the lime salts is never complete, especially when the filtration follows the saturation immediately, a very much smaller quantity of lime should be precipitated by pushing the saturation still further. From this standpoint there can be no question as to the favorable influence of a saturation upon graining yielding sugars which are neutral to the test of red and blue litmus paper.

**Conclusions as to when and how to use sulphurous acid.**—It has been proposed to use sulphurous acid in numerous other forms and at different phases of the manufacturing process, but very few of these suggestions ever found practical application. For example, STENZEL sulphured the after-products; VIVIEN and MESSIAN* used sulphurous acid upon the remelts of sugar refineries, and MONNIER † urged that raw sugars be sulphured. By reviewing the entire question from the standpoint of the data given in the foregoing pages it is not possible to draw any practical conclusion as to the most desirable phase of sugar manufacture for the application of sulphuring, and as to the conditions under which the operation should be conducted there is considerable discord among the leading experts. Upon general principles, however, it may be said that if neutrality is not exceeded the sulphuring may be done at any temperature. In an acid solution it is always recommended to effect it below 56° C. As regards the most desirable alkalinity the ultimate object should be to produce sugars that are thoroughly alkaline.

**Sources of sulphurous acid.**—The sulphurous acid considered in this chapter is that obtained by burning sulphur. In reality the gas thus generated is sulphurous anhydride, and it is only in contact with water, in the juice, etc., that it is changed into sulphurous acid. It may be obtained by burning pyrites, etc. In many of the industrial arts it is simply an after product, in which case it undergoes several phases of purification, and finally is forced under pressure into suitable steel receptacles, where it liquefies, in which shape it finds its way into the trade.

At first in sulphuring beet juices in sugar factories solutions of sulphurous acid in water were used, but experience showed that this method had very little practical value and it is now obsolete. The chemical needed is made on the spot by burning sulphur in sufficient quantities to meet the demands of the juice or syrups

* S. I., 28, 261, 1886.

† Jahrb., 8, 316, 1868.

being treated, and very little of the liquid product is used, possibly on account of the expense. Sachs* says that sulphurous anhydride may be made in a Belgian factory by burning sulphur for less than two cents a kilo, while the liquefied sulphurous acid costs nearly six cents a kilo.

**Consumption of sulphur and sulphurous acid.**—From a theoretical standpoint 16 grams of sulphur should neutralize 28 grams of lime, but as about 50 per cent of the sulphur is lost it becomes necessary to allow 32 kilos for neutralizing 28 kilos of lime. Suppose that the problem consists in reducing the alkalinity of a syrup containing 45 per cent of sugar from 0.05 per cent to about 0.01 per cent. Each kilo of this syrup represents 3 kilos of beets polarizing 15 (no allowance being made for the losses). Consequently 100,000 kilos of beets would give $\frac{100,000}{3}$ kilos of syrup, in which there must be saturated 13.33 kilos $\left(\frac{100,000(0.05-0.01)}{3\times 100}\right)$ of lime, which represents 15 kilos $\left(\frac{13.33\times 32}{28}\right)$ of sulphur. All calculations being made it is found that the amount of sulphur needed is 0.2 per cent of the weight of the beets sliced.

**Liquid sulphurous acid.**—The sulphurous anhydride will liquefy when submitted to a temperature of 10° C. At the ordinary temperature, 20° C., it will also liquefy under a pressure of two and a quarter atmospheres. When allowed to remain at atmospheric pressure it becomes gaseous, absorbing from the environment the caloric necessary for its vaporization. In some German factories the liquid sulphurous acid continues to be used. It is sold in receptacies of 50 to 100 liters capacity, or in enormous tank cars holding 10,000 kilos. Instead of keeping these tank cars in the yards of the factory the product may be emptied into an obsolete monte jus, as has been proposed by Bartz.†

There need be very little apprehension in regard to explosion, as it is only necessary to keep the receptacle in some cool place. Even then subsequent difficulties arise, as when the cooled gas is used its flow is slow and freezes over the entire exit opening. If a stream of cold water is run upon an iron bottle containing liquid sulphurous acid the water will abandon as much heat to the acid as was removed by evaporation in the gaseous condition. The

* La S. B., 18, 151, 1889.

† Z., 38, 612, 1888.

liquid consequently retains the same temperature and pressure as would exist at 15° to 20° C., or a pressure of about two atmospheres. By the use of a well regulated valve it is possible to secure a continuous and constant flow of these gases into the juice. However, other precautionary measures have been taken. FERREY * proposes that the steel receptacles for the liquid sulphurous acid shall have a spiral inner boring, such as is used for cannon, under which conditions the chances for explosion would be considerably lessened. In reality there is never an explosion. The metal bottles are simply torn open and the gases escape through the rip. The bottles are directly connected with the sulphuring tanks by means of a lead pipe of 10 mm. diameter. The valve attachment permits one to keep the volume of escaping gas under control. All communications are closed as soon as the sulphuring is finished.

In order that no juice may penetrate the reservoir when it becomes empty and that there may be no pressure, a special retaining valve should be placed in the force pipe. CLAASSEN says that the liquid sulphurous acid is a fraction more expensive than that which is obtained by the simple burning of the sulphur, but it possesses many advantages under various circumstances, mainly in cases where only a small quantity of sulphurous acid is used and where it is desired to regulate exactly the quantity of gas employed.

**Kind of sulphur.**—The sulphur used in European beet-sugar factories is a refined product imported from Sicily, and is very pure. In some special cases, or in an emergency, an inferior sulphur, such as that distilled from pyrites or produced in the regeneration of after-products of soda factories, may be employed. Sulphur melts at 114.5° C., boils at 440° C., and its vapor burns when it comes in contact with air, giving sulphurous anhydride. The kind of sulphur used must be taken into consideration, as the furnaces now employed are not suited to much of the raw material sold.

According to AULARD the natural sulphur will give, weight for weight, a decoloration and an epuration far more complete than can be obtained with precipitated sulphur chemically gained. ERNOTTE † asks if this property may not possibly be due to impurities. He very justly points out that if the sulphur is pure the resulting sulphurous acid will be equally pure, whatever be the origin of the sulphur, and VIVIEN and PELLET entertain the same view. Herein, according to AULARD, lies the delicate point at issue. which

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* C., 5 March 1898. † Bull. Synd., 27, suppl., p. 235, 1899.

is the purity of the raw material used. When sulphur is heated to boiling point in contact with defficient air for its complete combustion it will deposit in the form of a powder and thus tend to obstruct the piping which conducts the gas to the sulphuring tank. When sulphurous acid is heated to 1200° C. it entirely decomposes into oxygen and sulphur. At a lower temperature and in contact with an excess of air the sulphurous anhydride will be transformed into sulphuric anhydride. As pointed out in the foregoing, the destructive influence of the latter has been very much exaggerated. However, most of the sulphur furnaces have sublimators as a precautionary measure to hold back the distilled sulphur. There is also a washer that retains all traces of the sulphuric acid formed during burning, and thus prevents its subsequent inverting action. The preparation of sulphurous anhydride for sugar factories was first introduced by CALVERT.* The gas is generated in small special furnaces which are more or less faulty.

**Sulphur furnaces.**—There are numerous types of sulphur furnaces. They all consist of a horizontal combustion chamber, the sides of which are cooled by the circulation of cold water, and there is also a cooling column in which the sulphur vapors may condense. The combustion chamber is closed by a special door and has an entrance air pipe for the burning of the sulphur. The sulphur is generally placed in a saucer sufficiently large to hold 50 to 200 kilos, and is subsequently lighted. The characteristic differences in the existing types of sulphur furnaces lie in the automatic introduction of the sulphur in those portions of the apparatus where the sublimated sulphur is deposited and in the working of the gas generated.

These furnaces should be built so as to offer no objectionable features to the workmen in charge, and so that the sulphur cannot sublimate in the piping connected with the furnaces; for if these are clogged in this manner it will diminish the activity of the furnace, resulting in a poor sulphuring of the juices. A German model of a sulphur furnace is shown in Fig. 254. It consists of a cast-iron horizontal cylinder *P* closed in front by a suitable door. In this cylinder is placed the tray *M* already filled with sulphur, and the requisite air for the combustion enters by the pipe *T*. The vapors of sulphurous anhydride leave the furnace at the top where they enter a pipe *C* in which the sublimated sulphur collects. Air

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* Z., 12, 499, 1862.

when necessary may be introduced into $C$ through the cock $R$ and is intended to burn the sulphur vapors that have been carried forward The sulphurous acid vapors pass through the pipe $D$. The pipe $O$ permits the cleaning of the sublimating section when it is clogged by sulphur deposits. There are several other sulphur furnaces having very much the same arrangement, only above $P$ they have a basin which cools half the sides of the furnace. In some appliances no air is injected through $R$, which connects the interior of the furnace with the exterior air. By opening it, it permits one to ascertain how the combustion is progressing.

In many of the sulphur ovens there is difficulty in charging with sulphur without completely stopping the operation. In the

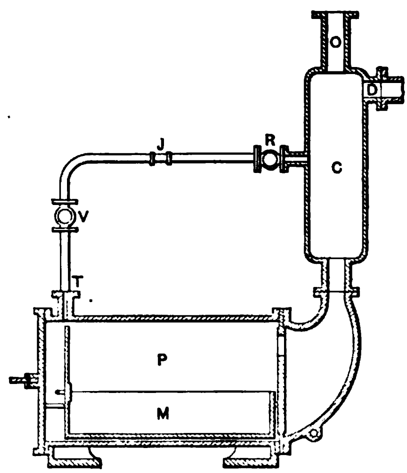


FIG. 254.—German Sulphuring Furnace.

VONHOF furnace (Fig. 255) this may be accomplished without in any way disturbing the general flow of the sulphurous acid produced. In the centre of $d$ is a cylindrical hopper, hermetically closed by a series of clamps $b$ holding down a circular plate. The valve $c$ is in the interior of the hopper and is worked from the outside. When charging $c$ is tightly closed; the requisite amount of sulphur is placed in the hopper, and by turning $c$ the sulphur falls into the oven. The air is introduced through a vertical pipe, shown on the left side of transverse section, and upon reaching the interior of the compartment it is distributed by a sort of inverted cone.

Another arrangement is the LACOUTURE furnace (Fig. 256). The air is forced to pass over a series of basins, $R$ in which is placed

lime for drying. This is supposed to diminish the chances of the formation of sulphuric acid during burning. The air then enters the main portion *D* of the furnace which is cooled by water contained in a basin, *B*, passes through the sublimator *S*, which is of a special construction, and then into the washer *W*, where it bubbles through a strata of water in which traces of sulphuric acid

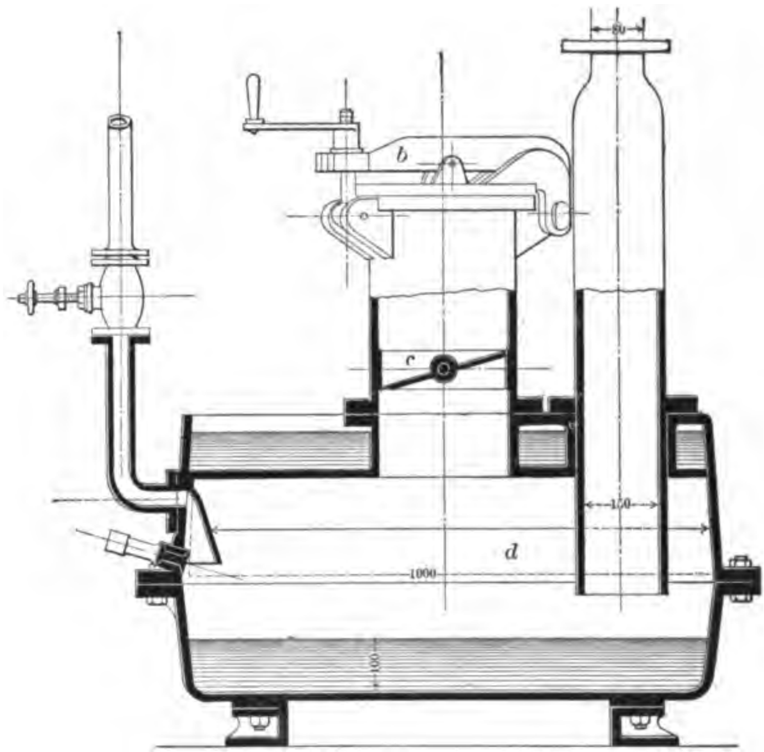


FIG. 255.—VONHOF Furnace.

are retained. The sulphurous acid then passes through *P* into the sulphuring appliance.

**Manner of conducting a sulphur furnace.**—When the sulphur basin is full the sulphur is lighted by throwing upon its surface lighted sulphur wicks, which are readily made by dipping ends of old ropes into the melted sulphur. After lighting the door is closed and air is allowed to circulate in the apparatus. The lighting may also be accomplished with a red-hot poker. In the working of a sulphur furnace it is important to prevent the sulphur from

distilling, or in other words, from being sublimated, which occurs when the temperature is excessive, hence the reason for the water-cooling device. Now and then one should touch the outer portion of the furnace to see that it is still warm and prevent its burning out. By opening a small cock placed on the furnace it is possible to determine by the escaping vapors whether it is still working. If the combustion has ceased the sulphur should be relighted without delay, for the decolorizing of the juice or syrup would other-

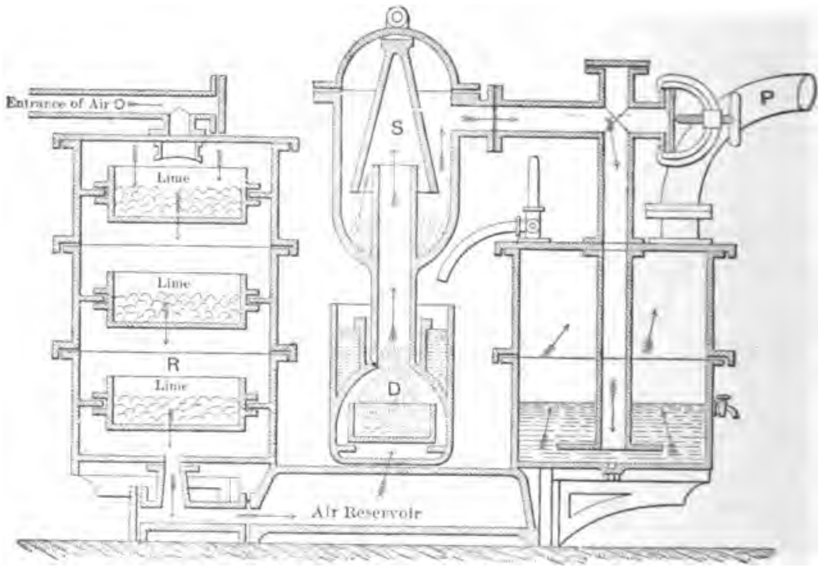


FIG. 256.—LACOUTURE Furnace.

wise be very irregular. It is important that the sulphur furnaces always be of reasonable dimensions, as otherwise an excessive volume of air would be necessary for keeping the furnace burning, and the sulphurous gas generated would be too dilute.

**Compression and suction of air.**—The air necessary for combustion may be introduced in several ways, either by compression or by suction. In most cases a compressor is used, and while no special appliance or combination is needed for this purpose its regular working is one of the essential conditions. The WESTINGHOUSE compressors give satisfactory results. They are worked by a small engine allowing certain variations in their efficiency. One HP. per 110 tons of beets sliced daily is sufficient. The pressure in the cylinder should never be more than one-half an at-

mosphere. In case of an accident certain advantages have been found in aspirating the sulphurous acid in the last compartment of a multiple effect, as by the obsolete SEYFERTH method.

One of the objectionable features of an air compressor is the necessity of keeping it constantly working, and when sulphuring is discontinued for a short period and the sulphurous acid escapes without doing any work a loss is incurred. An injecting arrangement may be more readily kept under control when irregularities occur. The device carries the gases forward into the sulphuring tank by means of the juice, water or steam. For ordinary sulphur furnaces, in which the sulphur is introduced by a manhole, the last method offers some important advantages, among which may be mentioned the possibility of recharging with sulphur when the furnace is in full activity.

The arrangement of BARTEL's sulphur furnace, which is a combination of injection and suction, is shown in Fig. 257. The sulphurous acid is generated in *A*, which is full of sulphur; the gases rise through the sublimator *B*, meeting during their passage suitable baffle plates, and enter *D*, where they are cooled by an exterior circulation of cold water. At the upper part of the apparatus is a compressed air or steam injector *N*. The sulphurous gas is drawn into *r* from which it passes into the sulphuring tank. The working of this furnace may be regulated in two different ways—either by modifying the injection, or by the small disks *b*, which close or open the air passages. Objections to the use of steam are the dilution of the juice and the possibility of inversion through the action of the high temperature. In the PORAK apparatus the sulphurous acid is drawn forward by a water tromp working with a saturated sulphurous acid solution in water. The water and the gas are separated in a closed reservoir, the water is pumped back into the tromp, and the gas continues toward the sulphuring tank. In the QUAREZ method the juice itself feeds the injector.

**Pyrites furnace.**—Mention may be made of experiments having in view the reduction of the cost of sulphurous acid preparation. It has been proposed to use pyrites,* which, to give the same results, cost three times less than sulphur. The pyrites are burned in a special receptacle and the resulting sulphurous acid is collected in a column in which water circulates. This water is subsequently heated by the waste gases from the pyrites oven. The pure sul-

* S. B., May 1901

phurous acid gas is thus liberated under a pressure corresponding to about one meter of water. As this gas does not contain oxygen it offers certain advantages over the sulphurous acid obtained by regular methods, for under these circumstances one need have very little apprehension in regard to the formation of sul-

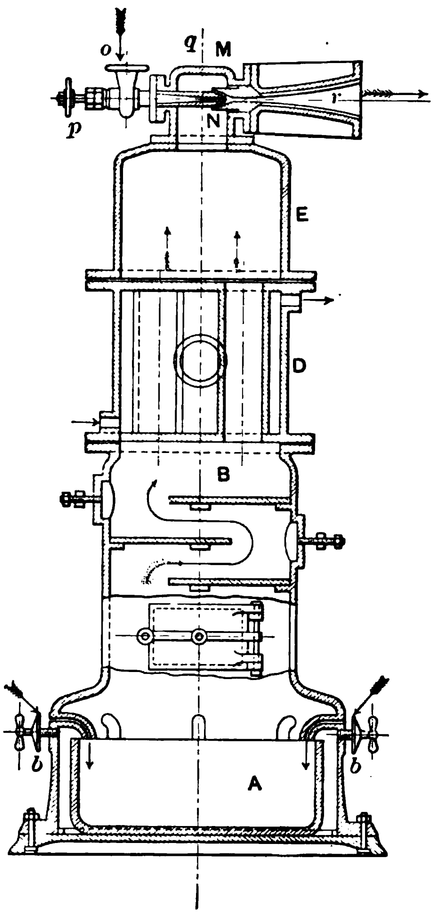


FIG. 257.—BARTEL'S Furnace.

phuric acid, so destructive in its action upon sugar, of which even with great care, frequently a certain quantity escapes and is carried forward owing to the faulty construction of the washer. At a sugar factory coming under the writer's notice the furnace burned about 1300 pounds of pyrites per diem and took up com-

paratively small floor space. One workman can take charge of the appliance during the day. The sulphurous acid is continuously generated and may be used in any continuous sulphuring appliance.

**Quantity of the sulphurous acid gas.**—The gas from a sulphur furnace never can contain more than 20.8 per cent of pure sulphurous anhydride, and often contains only 7 per cent. Upon general principles it is held that for a satisfactory average working the quantity is 15 per cent. The sulphurous acid obtained with pyrites can never reach that percentage, for the reason that more air is required to obtain the oxidation of iron at the same time that the sulphur is burning. The liquid sulphurous acid may be considered very pure.

**Piping.**—The pipes connecting a sulphur furnace with the sulphuring tanks are generally cast iron. Their diameter should be sufficient to prevent any possible obstruction. At all the elbows the pipes are arranged in a cross, the ends of which are closed with a suitable iron disk which may be taken off when it is desired to remove with a hot iron the sulphur deposited on the sides, which would entirely clog the pipes. The piping has suitable valve connections which allow the sulphurous anhydride to escape into the air when not being used in the sulphuring tanks. Considerable attention should be given to this valve that the gases may not escape through a leaky joint. In certain special cases coming under the writer's notice a cooling device is placed at intervals on the pipe. When the sulphuring furnace is properly constructed and handled the escaping gases are sufficiently cooled and a further reduction of temperature is unnecessary.

**Sulphuring tanks** are constructed on very much the same principle as the carbonatating receptacles, but are not so high and are of smaller capacity. The gas distributors have frequently the same arrangement in each case. The heating coils should be of iron rather than of copper, as the latter is soon worn out. The heating is frequently necessary as the juices cool during sulphuring and cannot then be readily filtered.

The LACOUTURE steam-coil combination is shown in Fig. 258. The gas enters by $C$ and is distributed through a lead branch combination $M$. The four lead pipes $D$ have suitable perforations allowing the gas to escape. It is claimed that by this arrangement the gas is very equally distributed through the juice being sulphured. In some cases the tanks are cylindrical and have central distributing agitators. The distributor is connected with

the piping of the sulphurous acid gas by valves with lead joints or ends of rubber pipes held together by suitable screws. Unfortunately these harden after a time, and although they may be softened by boiling for 15 minutes in a 5 per cent sodic solution, it is better to renew them. In Fig. 259 is shown the LACOUTURE sulphurer valve. The principal part *P* is of rubber, while the valve *V* reposes upon a metallic seat. The combination may be readily mounted and unmounted. Sometimes the gas is drawn from the sulphur furnace by means of an injector placed upon the chimney of the sulphuring tanks. To prevent the nozzles of sulphurous acid in-

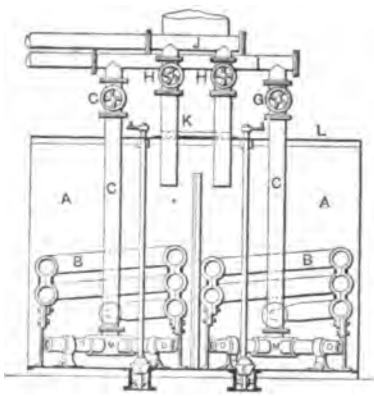


FIG. 258.—LACOUTURE Sulphurer.

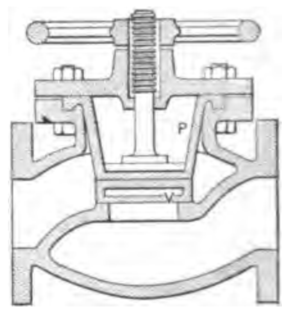


FIG. 259.—LACOUTURE Valve.

jectors from being attacked by the acid during beet-juice epuration it is proposed to make these nozzles of porcelain, which is much cheaper and lighter than metal.

Many factories in France use continuous sulphuring appliances with considerable success. Among the most successful and the best is the QUAREZ combination (Fig. 260). It consists of a basin *S*, in which the sulphur is burned. The door through which the sulphur is introduced closes very tight. The air enters from underneath and is dried by passing through several layers of quicklime. The resulting gases pass through the cooling reservoir *R* and into the sublimator *K*. The juice to be sulphured is introduced into the smaller division *D* of tank *T*. The pump *P* draws the juice up and forces it into the injector *E* and when it circulates downward through *N* the sulphurous anhydride from the sulphur furnace is drawn with it. Before entering *T* they will have been thoroughly mixed. The gas that has not been absorbed will bubble through

the mass of liquid in the tank. After the sulphuring the decolorized juice or syrup runs off through $K$.

During the sulphuring samples of the juice are frequently examined, and if it is found that the desired alkalinity has not been reached the pump is made to work more rapidly, the volume of the gae introduced becomes greater, and the general circulation of the apparatus is increased. If the alkalinity is too low, the re-

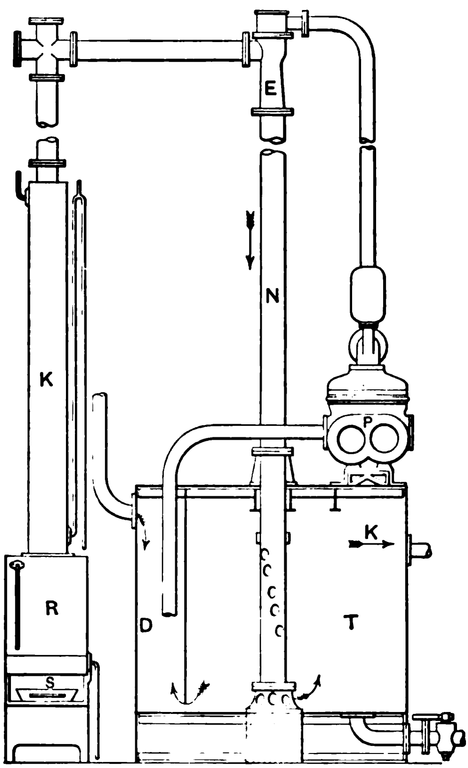


FIG. 260.—QUAREZ Sulphurer.

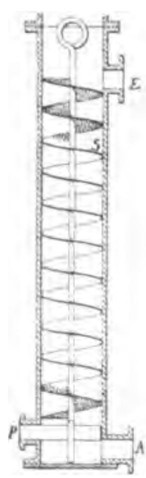

FIG. 261.—LIMPRICHT'S Sulphurer.

verse operation is resorted to and the number of strokes of the piston per minute is lessened. When for one reason or another the arrival of juice or syrup decreases the pump is stopped. If in the next phase of the operation the sulphured juices cannot be handled the flow into $D$ is stopped and the pump ceases working.

A new * continuous sulphuring appliance (Fig. 261) consists

* S. B., April 1900.

in a metallic cylinder, in which the liquor to be treated descends by a sheet-iron helix *S* and falls through a series of holes in a spray; the sulphurous gas is forced in from the bottom and the alkalinity may be regulated to suit the requirements of the situation.

**The practical application of sulphuring** does not present any special difficulty, provided that the man in charge of it carefully watches the alkalinity and makes the necessary corrections during the different phases of the operation. It is to be noted that continuous sulphuring may be effected in any of the existing appliances by regulating the entrance and departure of the juice treated as well as the volume of sulphurous acid used.

With sulphurous acid obtained by the combustion of sulphur the percentage varies considerably with the conditions under which the combustion has been produced, more attention should be given to the saturation. As a general thing no lime is added to the juices or syrups. A juice having an alkalinity of 0.07 to 0.15 per cent will throw down after saturation at boiling-point a certain granulated precipitate, which will surround and carry off any fatty precipitate that may be present. Under these conditions the filtration offers no difficulty. If, on the other hand- the non-saturated concentrated juice shows only a very slight alkalinity, owing to a previous excessive saturation of the non-concen, trated juice, there will follow very little precipitation during the new saturation and a poor filtration will result. A small addition of milk of lime is frequently helpful, but it would appear that the concentrated juices upon leaving the multiple effect before being saturated have considerable alkalinity and are readily filtered.

After sulphuring the juice is filtered at a pressure head of 2 meters either through filter presses or special mechanical filters. In some exceptional cases this filtration offers certain difficulties, especially when the alkalinity of the juices before sulphuring is too low. It is then desirable to add lime, and if this does not meet with success wood-flour, freed from its resinous substances, may be used, as explained under another caption.

## CHAPTER VIII.

### OTHER EPURATING AGENTS.

NUMEROUS chemicals have been proposed as epurating and decolorizing agents for juices, syrups, etc. In order that the reader may form a slight idea of the vastness of the subject a short list of some few of the compounds which have been proposed and tested is given herewith. Von LIPPMANN [1] published a list of 288 chemicals that have been used and suggested. The following alone are of especial practical interest and are not necessarily included in said list:

**Sulphur acids and their combinations.**—Sulphuric acid,[2] sulphurous acid,[3] sulphite of aluminium,[4] acid sulphite of lime,[5] hydro sulphurous acid.[6]

**Phosphoric acid and its combinations.**—Phosphoric acid [7] and various phosphates.

**Oxygen, halogens, and their combinations.**—Oxygen (gaseous),[8] ozone,[9] oxygenated water,[10] chlorine,[11] hydrofluoric acid.[12]

**Alkalies, alkaline earths, and their combinations.**—Quicklime, hydrated lime,[13] chloride of lime,[14] carbonate of lime,[15] hydrate of baryta,[16] barium bioxide,[17] barium chloride,[18] sulphide of barium,[19] hydrated strontia,[20] magnesia,[21] dolomite.[22]

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1 Z., **47**, 832, 1897.
2 Lippmann. Geschichte, p. 407.
3 Bull. Soc. Enc., **10**, 56, 1811.
4 L., **44**, 455, 1894.
5 Ding. Polyt. Journ., **117**, 136.
6 Oe.-U. Z., **26**, 737, 1897.
7 Z., **9**, 433, 1859.
8 S. I., **36**, 150, 1890.
9 Ber. deuts. chem. Ges., **2**, 64.
10 Z., **11**, 392, 1861.
11 Z., **44**, 458, 1894.
12 Z., **15**, 43, 1865.
13 Lippmann. Geschichte, pp. 134, 287.
14 Z., **44**, 447, 1894.
15 J. d. f. d. s., **16**, 22, 1875.
16 Z., **40**, 590, 1890.
17 D. Z. I., **18**, 1824, 1893.
18 Ber. deuts. chem. Ges., **15**, 1471.
19 S. I., **26**, 682, 1885.
20 Z., **32**, 986, 1882.
21 Z., **13**, 128, 1863.
22 Ber. deuts. chem., Ges. **6**, 155.

**Metals and their combinations.**—Alumina,[23] clay,[24] fluoride of aluminum,[25] quartz and ferric clays,[26] hydrated sesquioxide of iron,[27] permanganate of potash,[28] lead oxide,[29] hydroxide of tin.[30]

**Organic substances and their combinations.**—Tannin,[31] oxalic acid,[32] formic-aldehyde,[33] alcohol,[34] phenol,[35] white of egg,[36] blood,[37] sawdust,[38] sawdust made from wood fibre, etc.,[39] peat and lignite,[40] wood charcoal,[41] boneblack.[42]

**Electrolytic substances.**—Coal,[43] iron,[44] copper,[45] zinc,[46] platinum,[47] lead,[48] oxide of lead,[49] aluminum,[50] alumina,[51] peroxide of manganese,[52] alkaline earths,[53] baryta salts.[54]

Many of these substances have been applied in the diffusion battery, some upon the juice only, but mainly upon diffusion juices during defecation, upon non-concentrated juices, and also upon concentrated juices and after-products. Numerous other epurating agents not included in the number cited have been suggested; but the use of most of them is irrational. Some few substances may be used under very exceptional conditions. The methods suggested, considered as a whole, are generally too expensive to be of any practical value. Many of the substances are simply poisons, and frequently their presence is not detected even when combined with the final sugar; but they will in all cases be found in the molasses, and the utilization of this residuum for cattle feeding is then out of the question. In cases where it is not intended to effect the epuration of diffusion juices before defecation, any method should show its efficacy in eliminating the non-sugar

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23 Lippmann. Geschichte, pp. 135, 295.
24 Z., **35**, 361, 1885.
25 Z., **15**, 525, 1865.
26 D. Z. I., **22**, 1104, 1897.
27 S. I., **47**, 451, 1896.
28 J. d. f. d. s., **35**, 51, 1894.
29 Bley. Zuckerbereitung, p. 126.
30 Lippmann. Geschichte, p. 368.
31 Z., **9**, 331, 1859.
32 Ibid.
33 Chem. Ztg., **20**, 12.
34 Z., **11**, 522, 1861.
35 D. Z. I., **9**, 7, 1884.
36 Lippmann. Geschichte, pp. 135, 209.
37 Ibid., p. 324.
38 Z., **34**, 1269, 1884.
39 Z., **43**, 972, 1893.
40 Z., **4**, 452, 1854.
41 Lippmann. Geschichte, p. 368.
42 Ibid.
43 Z., **46**, 624, 1896.
44 Z., **46**, 625, 1896.
45 Z., **46**, 624, 1896.
46 Z., **46**, 625, 1896.
47 Z., **46**, 623, 1896.
48 Z., **46**, 626, 1896.
49 Ibid.
50 Ibid.
51 Ibid.
52 Ibid.
53 Z., **46**, 627, 1896.
54 S. I., **50**, 189, 1897.

the percentage of which should increase in the molasses. In this respect most of the methods proposed have not equalled expectations and, as before pointed out, when they promise favorably they are too expensive.

Owing to the vastness of the subject under consideration very few of the substances given in our list can be discussed in detail. It is interesting, however, to examine the principal ones that have had important applications and rendered service to the beet-sugar industry. The processes may be divided into several important classes: (1) those based upon the precipitation of sugar and its separation from the rest of the solution, this retaining the impurities; (2) epuration by which the impurities are eliminated from the saccharine solution; (3) decolorizing methods combined or not with other processes. As electrical methods of epuration belong directly and indirectly to the three groups they will be discussed under a separate caption.

**Precipitation methods.**—From the first attempts to manufacture beet-sugar up to the present time efforts have been made to isolate sugar in a solid state from saccharine solutions, leaving behind the impurities dissolved in the solution. The alcohol method also promised much, but experience soon showed that the losses of alcoholic vapors rendered the process too expensive to be of practical value. Hence, efforts were made to discover some process by which a combination with sugar would be formed, which combination could be readily dissociated in some subsequent operation entirely separating the original saccharine solution. Among the possible combinations are those with calcium, strontium, barium and lead, all of which form saccharates with the sugar. The practical working of these methods will be discussed under the caption of the desugarizing of molasses.

**Saccharate of lime.**—SYZFER * proposed to precipitate the sugar in the beet in the form of a tricalcic, which is the separation process as described by STEFFEN † in his various patents for working molasses, but instead of using this residuum the process is applied to raw juice. To arrive at any satisfactory results many laboratory experiments were made. For the third experiment he used diffusion juices fresh from the battery and heated them to 80° C., 0.2 per cent of quicklime was added; this was filtered, cooled and submitted to the operation of separation. The saccharate obtained

* D. Z. I., 25, 929, 1900.

† S. B. May, 1901.

was very clear, while the mother liquor, on the other hand, was a yellowish green. The composition of the saccharate was sugar 16.3 per cent, lime 14.0 per cent, purity 96.7 per cent, and of the mother liquor, sugar 0.65 per cent, lime 0.70 per cent. These experiments were repeated with the appliances used for separation, as applied to molasses, and were still more encouraging. The resultant saccharate was submitted to the action of carbonic acid, and the juice obtained was filtered and concentrated. The chemist in question believes that such juices are sufficiently pure and clear to be worked at once in pan and give a high-grade refined sugar.

The process gives juice of a high degree of purity, but demands the use of considerable water, which always involves sugar losses owing to the resulting solution. Great care is necessary to conduct the process according to prescribed rules, and the practical results show that the sugar percentage of the mother liquor is more than 0.7 per cent. To work the method on a practical basis enormous carbonatation tanks would have to be used. The saccharate must be very dilute before being sent to the carbonatation tanks, and to this objectionable feature it may be added that an increased amount of fuel is necessary to evaporate the excess of water in a multiple effect.

In the Becker Höndorf mode the sugar is precipitated as a **saccharate of barium.** The quantity of barium needed is very much less than the quantity of lime necessary, but, on the other hand, it is more expensive and is difficult to regenerate. Langen * precipitates sugar solutions by a barium compound. The sugarate of barium obtained is heated with barium aluminate; alumine is formed at the same time. It is claimed that the sugarate of the mixture is decomposed by carbonic acid and then filtered, and the calcinized product, when washed with water, gives a new solution of barium aluminate. One of the principal reasons for the abandonment of processes depending upon barium salts is the expense. and the hitherto difficult regeneration, this operation, even under the best of circumstances, demanding a high temperature. Furthermore, the furnaces, etc., to be used for the purpose are expensive and must be constantly renewed owing to their being injured by the formation of fusible glass. It is shown by experience that it is not possible to regenerate more than 80 per cent of the residuary carbonate at a reasonable cost, hence the necessity of constantly

* N. Z., 40, 224, 1898.

renewing the barium carbonate. This product costs $20 a ton, and is found mainly in England. If to this expense the cost of fuel necessary to obtain a temperature of 1400° C. be added, one can readily see why the chemical in question is not very extensively used.

Many of these disadvantages disappear if instead of forming the sugarate with the carbonate, a sulphide of barium is used, the latter offering no difficulty in regeneration. Experience shows that, in practical working by this method there are advantages in using the sulphide in excess; under these circumstances the sugarate formed represents all the sugar contained in the molasses. It is claimed that the raffinose, etc., and all the salts are completely eliminated in this way from the solution of molasses. The sugarate of barium is filtered and washed, the waters of the filtrate being collected and added to the mother liquor. The sugarate obtained is decomposed by carbonic acid and a pure sugar solution is consequently obtained.

The method was abandoned in France where no attempt was made to regenerate the sulphide, and it was simply run off with the waste water of the factory, which was unhealthy for the vicinity. The LANGEN sulphide of barium process is, however, in full working order at the Euskirchen, Germany, beet-sugar factory. The regeneration is conducted in the following manner: Carbonic acid is brought in contact with the mother liquors of hydrosulphide, the insoluble barium carbonate is precipitated and the sulphuretted hydrogen liberated. This gas is completely burned by being mixed with sufficient air to yield during combustion water and sulphurous acid ($H_2O+SO_2$). The resulting acid is absorbed by the moist residuary carbonate, when it is transformed into sulphite. It is dried and subsequently mixed with coal and then reduced in a suitable furnace with the requisite sulphate, so as to make up the losses. This method is rather tedious and offers several objectionable features. The carbonic acid used from lime kilns does not contain more than 33 per cent in volume of pure acid, consequently the pure sulphuretted hydrogen obtained is diluted to three times its own volume and complete combustion is not readily obtained. In theory, to entirely burn the $H_2S$, there are needed three volumes of oxygen or twelve volumes of air. The resulting sulphurous acid will be diluted into at least fifteen volumes of inert gas. The absorption of that quantity of diluted gas necessarily requires enormous surfaces of contact or considerable time, consequently the

product obtained under the best of circumstances is a sulphite mixed with a certain proportion of carbonate. All this mass is subsequently submitted to reverberatory fire. This has a serious drawback in that the reverberatory system used does not sufficiently utilize the heat, the sulphite is alone reduced and the carbonate undergoes very few changes.

Of late it has been pointed out that the barium sulphide may be regenerated by a much better method. In this case as in the former the mother liquor of sulphuretted hydrogen is submitted to a carbonic acid treatment, and all the barium used is obtained as a carbonate and all the sulphur as sulphuretted hydrogen. The carbonate is changed into a sulphide by bringing it in contact with sulphuretted hydrogen at a temperature of 400° to 500° C. Under these circumstances the carbonic acid gas is driven off. The reaction commences at 350° C., and the rapidity of absorption increases with the temperature which must not reach red heat as other reactions would then follow. In theory the sulphuretted hydrogen, carbonic acid and water might be indefinitely used. It is pointed out that by this method all the difficulties hitherto existing, such as destruction of the furnace, etc., are done away with owing to the comparatively low temperature at which the operations are conducted. The losses are very slight, and whatever they are, they can be made up by using an additional supply of sulphide of barium, economically prepared by the reduction of the natural sulphate of barium with coal. The sugar manufacturer can without difficulty prepare his own epurating material, barium sulphide, and regenerate it at the factory at very limited expense. The process has not been applied, or at least only to a very limited extent, to beet juices for which SEGAY * so highly recommended it. On the other hand it has been used for desugarizing molasses.

Among the objectionable gases connected with the baryta methods of manufacturing sugar may be mentioned the sulphuret of hydrogen which escapes when preparing the hydrated baryta by means of coal and sulphate of baryta. These factories which adopted † the latter process of manufacture have been compelled to abandon it, owing to an injunction obtained through the courts by neighbors of the vicinity.

While for a time the methods for extracting sugar from beets by the use of lead salts‡ had a certain number of advocates, these now

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* C., 9, 89,1900. † S. B., May 1891. ‡ S. B., July 1896.

seem to realize that there is danger to public health in the consumption of such sugar, which frequently contains traces of lead, the commercial determination of which is difficult, but the presence of which has been proven nevertheless.

**Other epurating agents.**—First of all may be mentioned a variation of the liming process. A very original method has been proposed by RIVIERRE for the defecation of beet juices. Instead of milk or hydrated lime it is proposed to use calcic carbide. The epuration is said to be very complete and will do away with second carbonatation. The liberation of acetylene gas follows, which can be used for illuminating purposes in the factory.

The use of **phosphate of lime,** neutral or acid, has been frequently recommended for the epuration of saccharine juices, either through the precipitation of lime from the calcic organic salts, or by other reactions. These methods have of late been attracting some attention. Excellent results have been obtained in using the residuum from steel manufacture as a fertilizer, and it is claimed that the processes of defecation and carbonatation may be more rapidly effected by adding these chalky phosphates to the juices in the diffusion battery. It is pointed out that if these furnace slags are examined under a microscope they will be found to consist of a conglomerate, consisting mainly of lime, constituting, as it were, a cement for the numerous phosphate granules. If the residuum in question is submitted to a sort of calcination, the carbonic acid will be liberated and the final product will consist mainly of caustic lime and lime phosphate. The calcinized product is broken up into small lumps and is placed in special receptacles into which the diffusion juice is forced. The juice thus epurated is filtered and then sent to the carbonatation tanks. The lime phosphate is renewed after the passage of the contents of a diffusor, and this operation is repeated as many times as there are diffusors in the battery. There are no sugar losses as the work is conducted in an alkaline medium. The details * of the basket handling have not been given in the foregoing.

The author has never been in favor of baryta or any other such poisonous salt in processes having in view the extraction of sugar from beets, but factories in France have had it in use for several years, and no complaints have been noticed. It is interesting to pass in review the process as given by the inventor, DU BEAUFFRET.

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* S. B., Dec. 1902.

**Baryta** may be used alone or in combination with lime. The sugar from molasses may be extracted by its use, and the saccharate thus obtained be employed in the general defecation processes of the factory. When during carbonatation it is employed in this form in combination with lime, the weight of final scums obtained is said to be lessened, and the syrups, being very pure, crystallize freely. In practice the baryta is used in a solution. For example, in a vat of 10 hectoliters capacity, with steam injection attachments, cocks for water and emptying, 400 kilos of crystallized baryta are added, with 500 liters of water. Steam is introduced, and when the baryta is dissolved sufficient water is added to fill the vat. (The capacity being 10 hectoliters, and 400 kilos being added, this gives a final solution of 400 grams baryta per liter of solution.) This solution will not crystallize. It is added to the beet juices as they leave the diffusion battery and are received in the measuring tank; for 10 hectoliters of juices, 1 kilo baryta or 2.5 liters of the solution are used. The combination with the juice is rapid, and considerable precipitation results. This insoluble product need not be removed, as carbonic acid is without effect on it. The lime is added in the regular carbonatation tanks. For 10 hectoliters of the diffusion juice, to which baryta solution has been added, 10 kilos of lime are added. If hydrated lime is used, allowance must be made for its degree of hydration, and prior to allowing carbonic acid to come in contact with the juices thus heated, a thorough mixing is necessary. Great care is needed in determining the alkalinity; it is calculated on a basis of calcic alkalinity (the juice should contain 1.2 grams of alkalinity per liter).

If working unripe beets the amount of baryta used must be increased by 50 per cent. The carbonatation is rapid with gases containing 25 per cent of carbonic acid. Decantation follows and filtration is not difficult. The second carbonatation offers no features of special importance, but it must be watched as to alkalinity. From this point the juices are worked as usual in evaporators, etc. It is claimed that a 300-ton factory using lime alone would need 9.4 tons per diem, while with baryta only 3 tons are required, which means a saving of 12 tons of limestone in twenty-four hours, with a corresponding decrease of residuum scums. The inventor has to his own satisfaction given practical proof that the capacity of a 300-ton factory is increased to 375 tons, and that the campaign need last only 80 instead of 100 days. The economy of the process may be calculated on the basis of 20 days' saving in time.

This process has been more or less modified, the soda being in some cases added to the diffusion juices, in others to the fresh cossettes in the diffusors. The main object of the soda is to facilitate the combination of baryta with the various organic acids. Before the diffusors of the battery are closed, there is added upon the surface of the cossettes sufficient soda carbonate to render the juice nearly neutral in its action. The quantity used should vary from one-half to one kilo per ton of beets worked. To the juice drawn from the battery is added 10 per cent of a baryta solution; the total is then heated almost to the boiling-point. The quantity of this chemical required varies from one to one and a half kilos per ton of beets worked; the other operations are conducted about as usual. It is claimed that the amount of lime needed during carbonatation is reduced by 35 per cent. The facts are that the process costs about 8 cents more per ton of beets than other processes in which it is not used. It is very doubtful if there is any special advantage.

The Gin and Leleux * method, in which aluminate of barium is used, may also be mentioned. Experts now declare that there is very little advantage to be gained over lime by the use of baryta even if it is combined with sodic carbonate. If any advantage is gained during carbonatation by the addition of baryta, it appears to be solely due to the density of the carbonate of baryta, the density of which is greater than that of carbonate of lime, and it consequently offers certain minor advantages in the quantity of *colloide* substances deposited. In order to precipitate the sulphuric acid contained in beet juices it has been proposed to use chloride of barium. The inventors of this process claim that the alkaline chlorides and the calcium chloride thus formed are less melassigenic in their action than the corresponding sulphates.

**Magnesia.**—All limestones contain more or less magnesia carbonate, to which is generally attributed an objectionable action in the epuration. However, with care, Bohlig and Dittenberger,† Appermann ‡ and many others have obtained practical results in the purification of beet juices by this means. Manoury submits one part of calcinized dolomite to the action of five parts of water and to the action of steam during one hour, in order to transform it into a magnesia hydrate. One thus obtains a milk of magnesia

* S. I., 46, 48, 1895. † D. R. P., No. 30,750, 1884.
‡ D. R. P., No. 339,134.

of 20° to 25° Bé. Precautionary measures are taken that the defecated and carbonated juices may not contain alkalies which would render the magnesia soluble. After the carbonatation of the juices a 1 per cent solution of milk of magnesia is added, and this is then run through the filter presses. The percentage of scums * by this process is only 4.7 instead of 10 per cent. The value of the refuse as a fertilizer is double that attained with ordinary lime, and the small cost of the process combined with the slight sugar loss are facts in its favor.

**Zinc.**—Chloride of zinc has been recommended as an excellent chemical to be used in second carbonatation. A certain quantity is added subsequently, and the result is decoloration, resulting from the combination of the lime forming calcic chloride and hydrated zinc. The hydrated zinc is said to be a precipitate absorbing a heavy proportion of the juice's impurities which may subsequently be eliminated by filter presses.

A new process of decolorizing beet juices,† and also melted sugars, in refineries, consists of the use of a zinc hydrocarbonate obtained by the precipitation of a raw zinc sulphate by an ammoniacal solution of soda. It is claimed that the carbonate obtained is very fine, and that its molecular condition is most advantageous for a combination with the coloring substances. The quantity of the chemical used varies with the juice being treated. When introduced into juices, the density can become 60° Brix, followed by heating from 60° to 70° C., then agitation for half an hour, followed by filtration in the filter presses. Experience shows that 1.5 to 2 per cent of zinc oxide produces the same result as 30 to 35 per cent of boneblack. The hydrocarbonate of zinc may be regenerated from the filter-press scums without leaving the filter, it being sufficient to run a 1 per cent solution of ammoniacal soda heated to 70° C., which is subsequently washed out with water. If the hydrocarbonate becomes impure from having taken up part of the coloring substance it may be treated with hydrochloric acid. It is said that as hydrocarbonates are insoluble in saccharine juices, there need never be the slightest apprehension of their containing even a trace of zinc.

This method has been somewhat changed ‡ since it was first used as a new process. The agents used are oxalic acid and moist hydrocarbonate of zinc. Raw sugars may be rapidly purified

* S. B., May 1890. † D. Z. I., 23, 1112, 1898. ‡ S. B., Sept. 1902.

the operation consisting in first forming a syrup with a density of about 30° Bé. A solution of oxalic acid is then added in the proportion of 1 gram per kilo of raw sugar, and the hydrocarbonate of zinc is added to the syrup mixture, the amount being 1 kilo per 100 kilos of raw sugar. The mixing is done mechanically and is followed by filtration. The resulting sugar will be first grade and perfectly white. One characteristic claimed for this mode is that the two chemicals used, when brought together, combine and in the properly strained and filtered syrup all traces of them will have disappeared. It is said that the action of the moist zinc carbonate is more satisfactory than that of the dried salt.

**Alumina.**—GANS suggested the use of hydrated aluminum for the epuration of any saccharine solution. The chemical is a well-known sugar laboratory product. It is proposed to add 1 to 10 per cent of milk of alumina to cold juices and to follow this by a filtration. The milk of alumina contains 0.5 per cent of alumina, and to prevent its decomposition the inventor adds a few drops of tartaric acid per liter. Efforts have been made to produce alumina in the sugar solution and with this idea in view numerous chemicals have been suggested. Among the latest of these efforts may be mentioned the one in which one-half a kilo of alumina sulphate is added to 300 liters of beet juices direct from the diffusion battery. This is followed by heating to 85° C. A small quantity of milk of lime is subsequently added, the juice is boiled for five minutes and then filtered. There is formed a hydrate of alumina and a calcic sulphate, and as they are insoluble they are said to carry down all the impurities contained in the beet juices.

Another method for the production of alumina in saccharine solutions consists in introducing an aluminum powder in small quantities into the triple effect every fifteen minutes, the amount being regulated so that the maximum quantity used shall be 2.5 kilos per 100 tons of beets worked. In exceptional cases of very superior and healthy beets the quantity may be reduced to 1 kilo per 100 tons of beets. The theory of this method is as follows: In the presence of alkalies contained in the juice there will be formed insoluble aluminates which will precipitate, effecting a first epuration. The formation of these aluminates occurs during the oxidation of the aluminum in contact with water. There follows a decomposition of the water with generation of hydrogen the bubbles of which rise and oxidize in contact with the coloring substances, decomposing them, in other words, a decoloration of the juice

takes place. Experience appears to demonstrate that a considerable fuel economy results, owing to a better utilization of the heat, which is said to be mainly due to the great conductibility of every particle of aluminum in motion in the saccharine liquor, the facility of liberation of the watery vapor under the action of the escaping gases and the motion of the pellicles of metal. This aluminum powder may be purchased at the rate of about 60 cents a pound so that its use involves an expenditure of $3 for 100 tons of beets, or 3 cents per ton of beets sliced.

Sulphite of protoxide of iron has been used by ENGLERT and BECKER * for purifying beet juices. The sugar juices are saturated until they have an alkalinity of 0.03 to 0.04 per cent. They are then boiled and the iron sulphite added until the alkalinity is reduced to 0.01. The precipitate is separated by running the liquor, while warm, through filter presses.

LEFRANC and VIVIEN have attempted to eliminate potash from beet juices by rendering it insoluble as a fluosilicate of potassium. Several authorities † condemn certain features of this method. Instead of using a fluosilicate of lead, as the first patents called for, a ferric fluosilicate is now recommended. Baryta is another substance used in connection with the fluation method. For working 500 tons of beets per diem 1700 kilos of this chemical are required, and it is pointed out that there are decided objections to such extended use of a violent poison. Manufacturers are recommended not to introduce hydrofluoric acid or its combinations into beet juices. Chemicals of all kinds should be very sparingly used in beet-sugar manufacture.

Among the **organic substances** may be mentioned oxalic acid ‡ which has been used for the elimination of calcic salts and coloring substances contained in beet juices. After the juices of second carbonatation have been properly filtered, they are mixed with oxalic acid until the reaction is slightly acid. The oxalate of lime formed is separated by filtration.

Tannin has found some applications in the purification of beet juices. These are saturated in the ordinary way to 0.01 to 0.05 and the tannin is then added until the precipitation is very cloudy. A gelatine solution is mixed with the foregoing juice and the whole allowed to settle for half an hour. The juice is then filtered and the residuum washed with hot water. Instead of gelatine,

* S. B., Feb. 1888. † S. B., May 1892. ‡ S. B. Jan. 1901.

albumin may be used. A small quantity of phenic acid will prevent any alteration of the tannin.

**Decoloration processes.**—The chemical decoloration processes for saccharine juices may be divided into (1) oxidation of the coloring substances; (2) reducing the coloring substances by the removal of the oxygen; (3) precipitation of the coloring and foreign substances.

PECHNIK, BOGEL and STEIN have recommended that oxygenated water be used for beet juices. It easily decomposes into oxygen and water as it contains twice as much oxygen as water does. The formula of the latter being $H_2O$ the water in question would be $H_2O_2$. It may be prepared in many different ways. It would be impossible to use the so-called oxygenated water as sold in the market for the purification of juice, as it contains hydrochloric and nitric acids, which, if neutralized, would give rise to soluble chlorides and nitrates, impossible to eliminate from juice or syrups. On the other hand, it is possible to manufacture oxygenated water containing no foreign substances other than the phosphoric acid necessary for its conservation. When about to be used the phosphoric acid may be neutralized by lime water, forming a phosphate of lime, which precipitate may be most easily separated by filtration. When the oxygenated water thus prepared is in the proper condition it is mixed with syrups, and the oxygen is set free by the addition of pulverized boneblack. This gas combines with the organic coloring substances. After several hours repose the liquid should be heated to 90° C. and filtered. The filtrate is colorless and is ready to be sent to pan.

This process may be applied to syrups of sugar factories and refineries. It is claimed that when refining granulated sugar remelting is unnecessary. The sugar to be treated is crushed in one case and in the other a syrup at 36° Bé. is prepared and mixed with 3 per cent of oxygenated water, to which one-half of 1 per cent of pulverized boneblack is added, followed by filtering. The liquid is then perfectly colorless. This filtrate is combined with the crushed sugar, so that the product obtained is very like a *massecuite;* 1 to 2 per cent of oxygenated water is then added and heating to 50° or 60° C. is necessary. The mechanical transformation into white sugar demands a special appliance which cannot be described here.

STEIN and CROSSFIELD * strongly recommend that the juices

* Oe.-U. Z., 28, 181, 1899.

of second carbonatation be acidified after the addition of oxygenated water. This decomposes the coloring substances and allows subsequent operations to be more complete, as the resulting elements from these decompositions give alkaline reactions. The precipitates are separated by filtration. It is also proposed to submit the juices to a phosphoric acid treatment and to add sulphate of aluminum or tannin.

The experiments of PETERS * demonstrated that saccharine juices undergo an important change when submitted to the action of ozone, and that the decoloration in certain cases may reach 35 per cent. By submitting beet juices to the simultaneous action of ozone and electrolysis, the decolorizing effect is still greater. A new ozonator † consists of a semi-cylinder, generally made of cast iron. The inside surface is covered with enamel, and the receptacle is covered with a thick sheet of glass extending its entire length. The glass is pierced with a series of rods held in position by suitable nuts, and acting as supports for metallic strips, forming a cylinder corresponding to the other half of the cast-iron semi-cylinder just mentioned. The strips are placed in communication with one pole of a high-tension battery, and the bottom of the half-cylinder with the other pole; a liquor of some kind fills the apparatus and plays the rôle of a resisting medium. Air that is to be treated by ozone circulates between the cast-iron receiver and the metallic strips.

VERLEY describes an ozonator consisting of a slate slab, upon which is fixed a highly polished plate of aluminum. This table is placed upon isolating supports. At its centre is a hole through which the ozonated air is drawn. Small strips of glass of 4 mm. thickness are stuck to the aluminum plate so as to form a series of straight passages, forcing the gas to circulate before escaping at the central orifice. Upon these strips a looking-glass is placed in such a position that its silvering will be on the side opposite the aluminum plates, which are in communication with the upper part of the glass through the poles of an alternator. Electrical sparks are created between the two plates. If the air with which it comes in contact is drawn through the central orifice it will be highly charged with ozone. Special transformators are used, which give as much as 400,000 volts. The sugar factory where this method was introduced sliced 200 tons of beets per diem.

* N. Z., 41, 237, 1898.

† S. B., Feb. 1900.

The machine was 100 H.P., with an alternator of 300 amperes of·250 volts. The current was divided into ten sub-currents, each of which worked a transformer, produced a secondary current of 12,000 volts, and worked ten ozone appliances, or a total of 100 ozonators.

The inventor* recommends that the alkaline juices from filter presses containing a small quantity of lime be submitted to the action of ozone or ozonized air, and that this be followed by sulphuring. The results obtained are said to have been most satisfactory. Oxygenized air is drawn through two receptacles in which the ozone is entirely absorbed by juices at 20° to 25° Bé. at 30° C., and a filtration follows. The juices thus obtained are darker than they were before the treatment, but they may be readily epurated in subsequent operations in which other substances are used. The juices are then sulphured until an acid reaction is reached and saturated with baryta. ANDRLIK,† who criticized this method, says that if lime instead of baryta had been used the results would have been equally satisfactory and it would have been considerably cheaper. The baryta treatment costs 1.2 cents per 100 kilos, while the ozonization of juices costs 0.3 cents. The purity of syrups is raised during evaporation on an average of about 1.15 per cent, the yield of sugar is said to be greater, and, furthermore, it is claimed that the crystallized sugar obtained does not have the characteristic beet odor.

It is pointed out that one of the objectionable features of these processes is the enormous motive power necessary for the preparation of the ozone. RANSON'S‡ investigations were for the purpose of producing ozone by other methods, such as adding to the juices small quantities of barium bioxide. As soon as this chemical is added to a saccharine juice oxygen in the form of ozone is liberated, the coloring substances are destroyed, and the baryta combined with the sugar is precipitated by carbonic acid from an ordinary lime kiln or one where the barium carbonate of a previous operation is being transformed or regenerated. A small quantity of sulphuric acid must be added to the sugar solution which runs from the filter presses so as to eliminate the last traces of the barium. The excess of acid is neutralized by adding the requisite amount of soda. This process is interesting from a laboratory point of view, but for

* Oe.-U. Z., **27**, 48, 1898. † B. Z., **23**, 341, 1898–1899.
‡ S. I., **47**, 497, 1896.

practical purposes it is doubtful if it will ever meet with much encouragement.

Epuration of saccharine juices with a permanganate combination of lime, baryta, etc., is said to offer certain advantages. Experience shows that when a cold sugar solution is brought in contact with a 25 per cent calcic permanganate solution a decoloration is slowly produced, provided the said solution is slightly acid. On the other hand, when the solution is neutral or alkaline the decoloration is much slower. If heated to 75° the reaction is more rapid and about 25 minutes are needed to effect a complete decoloration. If a 9 per cent solution of refined sugar is combined with 1 per cent of calcic permanganate and subsequently treated with carbonic acid, the changes in color will be from violet to red and then to a brownish red. The alkalinity is neutralized by sulphuring the solution. It is claimed that the percentage of invert-sugar formed is reduced to a minimum. The process may also be applied to syrups.

**Chlorine.**—Among the oxidizing decolorizing processes may be mentioned the KITSEE * process in which chlorine is used. This treatment is followed by the use of some substance which forms with the chlorine an insoluble combination readily eliminated in subsequent operations either by decanting or in other ways. It is said that no hydrochloric acid can be formed during this operation. The chlorine in question is injected into the saccharine juices under pressure, and this is followed by the injection of ethylene which combines with the chlorine to form an ethylene chloride. This substance floats on the surface of the liquid like oil and may be eliminated by decantation.

Among the reducing agents mention may be made of hydrogen. It was recommended by CRISPO, who proposed that this gas be brought directly in contact with saccharine juices.

The RANSON process is based upon the decolorizing properties of hydrosulphurous acid. This acid is generated when metallic zinc is brought in contact with sulphurous acid. It is an exceptionally powerful reducing substance, that is to say, it will remove the oxygen with considerable energy from substances containing this element especially the coloring substances of juices. Syrups are sulphured until they have an alkalinity that is thought satisfactory; then the regular filtration follows, after which the syrups

* D. Z. I., 26, 63, 1901.

must be cooled to 50° C. and again sulphured in large tanks. The mass is kept in motion and the sulphuring ceases when an acidity of 0.15 per cent is reached. To the liquid is then added 25 grams of powdered zinc and the agitation continues from 10 to 15 minutes, after which it is filtered at 70° or 75° C. The after products of the factory are submitted to very much the same treatment. The Ranson mode has undergone numerous transformations since it was first invented, the details of which cannot be given, as they would lead us very much beyond the scope of the present writing.

The use of tin salts for beet-juice purification is also recommended by Ranson.* An electric current is passed through a solution of stannic chloride, tartaric acid and caustic potash, when there follows a microscopic tin precipitate; this should be kept under water, away from air, so as to prevent oxidation. After having thoroughly washed this tin until there is a neutral reaction a paste is made, which should contain 80 per cent of water and 20 per cent of tin, and this is added to beet juices which have received a preliminary sulphuring. There is formed hydrosulphurous acid and a stannic sulphite, which is dissolved in the juice and soon decomposes into sulphurous acid and stannic oxide; then follows an important action on the coloring substances of beet juices. These combinations are insoluble. During this period there is also a mechanical epuration.

In one of the other Ranson † methods a solution of fluoride of zinc is added to saccharine juices to destroy their coloring substances through reduction. Before they are submitted to this action the juices are sulphured so that the reducing action of the hydrosulphurous acid and the sulphites will facilitate the action of the zinc fluoride. Lime may be added to precipitate the impurities formed in the juices and those which are the outcome of the decomposition of the coloring substances. Bruhns ‡ says that notwithstanding the continuous activity of the Ranson process, there is no invert-sugar formed; the oxide and the zinc powder are separated through a careful filtration, and the resulting sugar does not contain perceptible traces of zinc. This metal, however, collects in the residuary molasses, and whether this product can be desugarized remains to be demonstrated.

A well-known writer and expert chemist calls attention to some very important facts regarding the use of zinc in beet-sugar manu-

* D. Z. I., 25, 440, 1900. † Z., 51, 359, 1901. ‡ C., 6, 541 and 591*b*, 1898.

facture. The quality or composition of the metal has an important influence not to be overlooked; when the zinc is not absolutely pure many complications necessarily follow. It is a well-known fact that zinc, as used in the arts, contains substances combined with several other metals which are dangerous poisons; among these certain lead and arsenic salts may be mentioned. An example to the point is in the laboratory research for arsenic. Hydrogen is produced in the MARSH flask with zinc and when the metal contains traces of arsenic the results obtained are always very misleading. Evidently when zinc is manipulated by experts very white and pure sugar may be obtained, but the question remains: Are not those zinc methods in the hands of the ordinary factory employees sources of great danger to the general public? Hence, it should be a legal offence to allow other than chemically pure zinc to be used in a beet-sugar factory. These are facts not to be overlooked. It is to be noted that ENGLERT and BECKER * used hydrosulphurous acid for decolorizing beet juices nearly twenty years ago, and these inventors also claimed certain advantages for hydrosulphite of ammonia, barium, strontium, calcium, magnesia, aluminium, zinc, manganese, and iron.

## ELECTRICAL EPURATING PROCESSES.

**Historical.**—Among the first experiments in the purification of saccharine juices by electricity were those of CLEMENT † in 1848. The juices were heated to a high temperature and then submitted to a BUNSEN battery.

In 1875 GRAMME and COLLETTE ‡ applied electricity to the purification of molasses. The apparatus consisted of platinum electrodes, separated by parchment paper. The vat in which these experiments were conducted had a capacity of 350 gallons. More than one-half the salts were decomposed after twenty-five minutes. In 1879 several attempts were made in Louisiana to use this method.

The DESPEISSIS § porous-jar method did not attract much attention before 1884. Dialysis was the main principle of the invention. Each electrode of platinum or carbon was placed in an earthen jar filled with water and the carbon was immersed in a sugar

* D. R. P., No. 36,851, 1886.

† Sugar Specifications, No. 12,335, 1848.

‡ Bull. Chim. Belg., 8, 90, 1894.

§ D. R. P., No. 28,353, 1883.

solution, under which conditions the bases were separated from the acids. It was essential for even partial success that the saccharine liquids being treated should be properly diluted. By this method many filtrations were necessary. The fractional methods of electrolysis proposed during this year (1884) were numerous.

During 1866 some attention was given to an English process of ECCLES and FAHRING,* in which sugar was separated from the coloring substances and whitened by ozone produced by discharges from a high-tension electrical machine. The product was then submitted to the action of a current from a low-tension machine. For this purpose the carbon electrodes were separated by a porous partition, the sugar being on one side and a current of water on the other. The latter was supposed to carry off all the impurities.

Among the methods which have been put in practice may be mentioned that of MAIGROT and SABATES, of Cuba, a combination of osmosis and electrolysis.

**Classification.**—The electrical methods of epuration may be classified as follows: (1) Simple electrolysis with inert anodes; (2) simple electrolysis with soluble anodes; (3) electrodialysis with inert anodes; (4) electrodialysis with soluble anodes.

In the simple electrolysis the two electrodes are submerged in the saccharine solution; the current flows directly from one to the other in passing through the liquid, producing upon the surface of the electrodes, more or less complicated phenomena, depending upon whether the electrodes are inert substances, such as carbon or platinum, or soluble substances, such as lead or zinc.

In the electrodialysis one or even two porous partitions separate the electrodes from one another. In cases where there is but one partition the sugar is on one side and the water on the other; if there are two partitions the layer of sugar solution is between two layers of water. The impurities separated from the sugar in the solution are carried by the electrical current onto the two electrodes, and as at least one of these is submerged in water, the water will carry them off before an appreciable quantity of sugar has had time to pass through the porous partition.

**Sugar destruction through electricity.** — The experiments of GIN and LELEUX,† made to determine the extent of the destruction of sugar by the action of electricity, were conducted with a 5-volt current passing through carbonatated juices. The conclusion

* Bull. Chim. Belg., 8, 94, 1894.

† 2d Congress, I, p. 227, 1897

drawn was that even after fifteen minutes there was not the slightest change in the nature of the sugar contained in the solution. However, this limit must not be exceeded. The rapidity of the decomposition of sugar will be in direct ratio to the electromotive power. The kind of electrode also has great influence upon the electrical destruction of sugar. Without doubt the liberated acids also play an important part in this destruction. If these acids combine with the metal of the electrodes their action is lessened.

Battut points out that there is no destruction of the sugar through electrolysis provided soluble anodes are used. The passage of an electrical current through diffusion juices brings about a segregation of the impurities; the bases settle on the negative pole and remain in the liquid, while the organic acids are centred upon the positive pole, with which they combine, and most of them thus escape the secondary combination in the presence of the liberated alkalies, and are precipitated. The resulting epuration does not differ in any important measure from that realized through double carbonatation. By combining carbonatation and electrolysis the juices are made lighter in color.

**Action of electricity upon non-sugar.**—According to Bersch * a weak electrical current passing through raw juices will bring about the separation or decomposition of nitrogenous substances and albuminoids, coloring and pectic substances, while a stronger current will decompose the acids, organic and mineral salts, and finally the sugar. According to this authority an electric current will destroy the chromogene of coloring substances, and consequently lessen the color of the juice treated. By the application of a weak electrical current there will be deposited upon the surface of the electrodes the products resulting from the partial decomposition of the albuminoids. It is evident that if a porous partition separates the electrodes in the case of electrodialysis, the albuminoids coming under the head of colloids will pass only with great difficulty and will not be readily separated in an insoluble form from the solution. On the other hand, the cristalloids will pass rapidly through the partition, especially when helped by the action of electricity. The reverse is the case for electrolysis, for then the albuminoids are rendered more or less insoluble and may be separated by filtration. The action of electrical currents upon salts contained in saccharine juices is about as follows:

* S. I., 44, 34, 1894.

The metal is deposited upon the negative electrode, and as these are the alkaline metals contained in the juice they decompose water, forming a hydroxide of the corresponding metal in liberating hydrogen. If the liquor is acid there will form a salt of this acid and hydrogen. The acid radical of the salt decomposed by the electrolysis centres on the positive pole liberating oxygen. If the saccharine liquor is alkaline and we consider a weak acid the latter will be decomposed into carbonic acid and will combine with the alkali. When the alkalinity is excessive the transformations that occur are very difficult to follow. There cannot be the slightest doubt as to the epurating action of electricity, and as mentioned in the foregoing, all the impurities separated by lime from diffusion juices may be equally well eliminated by electrolysis. According to the experiments of BATTUT * the juices of second carbonatation may be still further epurated through electrolysis, and even when very small quantities of lime have been used during defecation, the purity may be raised as compared with the regular methods of working.

**Influence of the electrodes.**—The electrodes have considerable influence upon the epuration of beet juices. As previously shown, in some cases they can prevent sugar destruction by combining with the acid radical. If the metals are properly selected these radical acids form insoluble combinations with the metal of the electrodes. SCHOLLMEYER and DAMMEYER † have attempted to form combinations between the alkalies and the metal of the anodes. Zinc and aluminium were selected with this idea in view, these possessing the property of forming double oxides with alkaline metals. The electrodialysis of diffusion juices with lead anodes ‡ effects a most thorough epuration which may reach a purity of 97.2.

PALM § proposed that the cathode used for the electrolysis of juices be a metal, or an alloy, such as mercury, which is liquid at the temperature at which the operation was conducted. The liquid cathode would form an alloy with the alkaline metals decomposed through electrolysis, under which conditions water could no longer transform them into hydrates. After a certain interval the cathode would be so charged with alkaline metals that the metal of the cathode would have to be renewed to prevent

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* 2d Congress, I, p. 173, 1897, Paris.
† D. R. P., No. 76,853, 1892.
‡ 2d Congress, I, p. 212, 1897, Paris.
§ Oe.-U. Z., **29**, 221, 1900.

the alkaline metals from decomposing the water. The electrical current should be so regulated that when the alkaline metals are being redissolved in water the juice will have an alkalinity that will facilitate its subsequent working. The electrolyzer is cylindrical, and a well-arranged scraping device keeps the surface of the cathode perfectly bright. The anode is made up of sheet iron, or iron rods, vertically arranged in the direction of the cathode.

ASCHERMANN * claims that a perfect precipitation of the albumin is realized by electrolysis, and that there are no products of decomposition to contend with; he uses metallic sulphides, such as sulphide of iron, as electrodes. One of the greatest difficulties in electrolysis and electrodialysis is to keep the surface of the electrodes active. In one case they become covered with the albuminoids, etc., and in the other case with gas bubbles which polarize the two electrodes. A very clever plan for keeping the electrodes clean and consequently overcoming the difficulties just mentioned, consists in having them round and kept in constant motion between rubber scrapers. Under these conditions it is claimed that nearly all of the non-sugar is eliminated.

**Electromotive force, intensity and consumption of current.**—It has been shown that it is not desirable to exceed an electromotive force of 5 volts, and most of the applications of electricity to juice epuration adhered to this limit. A long series of observations on the electrical treatment of saccharine juices has led to the conclusion that the resistance offered to the current of electricity is a function of its concentration. The resistance of a sugar solution is also in direct ratio to its temperature, lessening as the temperature increases.

The intensity of the current varies greatly from one installation to another, depending upon the object in view, hence the force consumed differs with the process used. BATTUT's † experiments have yielded some important information. He concludes that in slicing 500 tons of beets per diem, there will be needed for the treatment of the resulting juice by electrolysis, using soluble zinc and lead anodes, the following power:

| | |
|---|---|
| Electrolysis of raw juices | 550 H.P. |
| Electrolysis of juices of second carbonatation | 240 H.P. |
| Electrolysis of epurated syrups | 400 H.P. |
| Electrolysis of molasses | 440 H.P. |

* D. Z. I., 27, 747, 1902. † 2d Congress, I, p. 227, 1897, Paris.

**Diverse views respecting the electrical processes.**—Nearly all the existing electrical processes are very expensive, and hence they have only a very restricted practical value, there being required considerable electrical energy and soluble anodes the metal liberated from which is not entirely used in the precipitation of impurities of the juice. Analysis shows that a large amount is lost as an insoluble oxide, or in solution in the saccharine liquor. There follows consequently a considerable waste of metal, but this cannot be obviated if the object in view is a satisfactory crystallization of white sugar.

According to CLAASSEN * the cost of the purification of beet juices by electrolysis, using soluble metallic anodes which form insoluble compounds with the liberated acids, is entirely too high to be of any practical commercial value; furthermore, the alkalies remain in solution and end by again being transformed when coming in contact with some acid. A real epuration of beet juices can be obtained only when the alkalies are entirely separated as by electrodialysis. These methods are also unfortunately too costly, due to the use of an intervening membrane, which, by its resistance, increases the quantity of electrical current needed. Moreover, a certain percentage of sugar passes through the porous membrane, and during this osmotic action water will flow in the opposite direction, which will always considerably dilute the juices.

CLAASSEN † says that the SAY-GRAMME process will not be a financial success, as it cannot possibly be economical to apply the method to juices as pure as those leaving the diffusion battery. There is another difficulty not to be overlooked which is that of keeping the joints perfectly tight. This savant made some experiments with electro-hydrosulphitation, which consists in the transformation of the sulphurous acid contained in juices treated by this chemical, into hydrosulphurous acid by electrolysis, using only a very weak current. With carbon electrodes the results were not satisfactory; lead electrodes, while interesting from a scientific standpoint are not to be recommended in practice on account of cost. These views are given simply to show that it is desirable to use considerable precaution in introducing the electrical process into beet-sugar factories. Evidently if motive power may be had at a nominal cost, and consequently the electricity be obtained under favorable circumstances, it would modify the CLAASSEN argument

* C., 7, 507, 1899.

† S. B., Feb. 1900.

in many respects. The arguments advanced respecting the use of soluble metallic anodes, however, always remain true.

**Practical working of electrolysis.**—The SCHOLLMEYER, BEHM and DAMMEYER * electrical process is applied to diffusion juices at 70° to 75° C., and lasts from 6 to 10 minutes, the impurities being subsequently separated by filtration. With a view to facilitating the filtration, 0.25 per cent of lime is added to the juices. The electromotive force is 5 volts. The filtrate is then sent to the first carbonatation, which is conducted in the usual way. In this case only from three-quarters to one per cent of lime is added. Through electrolysis the juice loses 77 per cent of its original coloration.

The mangano-electrical appliance of LAVOLLAY and BOURGOIN demands comparatively small floor space. The combination consists of two series of five electrolyzers, composed of very high rectangular receptacles, having each a capacity of about 1400 liters, which are arranged one beside the other with a slight difference in elevation between them. They are all connected by a special pipe, arranged so that one series of five is in full working order while the other is being cleaned. The juice enters the highest tank from the bottom, then gains its upper surface, runs off and flows into the second from the bottom, etc. About one-quarter of an hour is necessary for the juice to circulate through all the electrolyzers of the series, during which period it comes in contact with the electrical current. The average tension in the tanks is about 4 volts, each electrolyzer containing 9 zinc electrodes.

The juices, before being electrically treated, are combined with lime and manganate of lime. In the Souppes factory the diffusion juices from the battery are combined with saccharate of lime from the STEFFEN separation process, about 50 grams of calcic manganate are added per hectoliter of juice being treated and the juices are then heated to 60° to 70° C., subsequently being run through the electrolyzers. The transformations that follow during the passage of the electrical current are as follows: First, there is liberated a certain quantity of oxygen, the foreign organic substances are oxidized and become insoluble. After the treatment, the juices are pumped into the first carbonatation tank, the operation being conducted without addition of lime, and continuing until the alkalinity corresponds to 0.1 per cent of anhydrous lime. After one

* Bull. Chim. Belg., 8, 101, 1894.

series of electrolyzers has finished its work, it must be cleaned and the juice is then run through the other series. The cleaning is very simple and consists in removing the electrodes and thoroughly brushing the zincs.

After this treatment the juices are slightly heated and then run through the filter presses. To the clear juice are added 300 grams of lime per 100 kilos of beets, after which it is sent to the second carbonatation, where the saturation continues until the desired alkalinity is obtained. It is claimed that through this electrical treatment the juices are to a certain extent sterilized and undergo no change even in contact with air for a long period. The turbid juices of second carbonatation are filtered, this operation offering no difficulty. Evaporation is the next operation, which offers nothing of special interest.

Besides this mode another may be mentioned which depends upon a galvanic action. VERLEY * has proposed to use a so-called coppered zinc for beet-juice epuration. This may be prepared in a special manner by mixing powdered zinc with a 1 per cent solution of copper sulphate. To the juice, heated to 80° C., is added 1 per cent of the powder. After a thorough mixing during one hour there follows a voltic reaction, which appears to have an important reducing effect on the coloring substance of the juice. Before submitting beet juices to this process it is generally found desirable to bring them in contact with ozone in order to obtain a more complete decoloration; however, this is not indispensable. The 1 per cent coppered zinc used already represents an excess, but the zinc deposited may be recovered after decanting, followed by washing, and again combined with copper sulphate. This may be used at once during the process of manufacture.

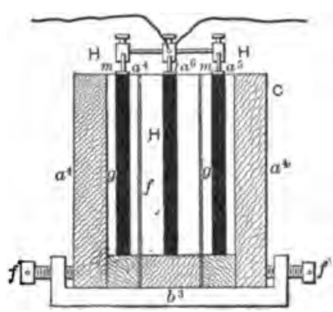

FIG. 262.—MAIGROT and SABATES Electrodialyzer.

**Electrodialytic methods.** — The electrodialyzers of MAIGROT † and SABATES (Fig. 262) are arranged so as to form a battery of 4 to 6 meters in length, 0.25 meter wide and 0.30 meter deep. Each of the receptacles *H* is divided into three compartments by means of parchment paper, $S^2$, and contains an electrode. The

* S. B., Oct. 1901. † Bull. Chim. Belg., 8, 94, 1894.

middle compartment, *f*, contains the positive electrode, *l*, and the two others, *g*, hold the negative electrodes, *m*. The compartments of the different sections are connected in such a manner that the juice circulates successively through all the central divisions and the water through the lateral portions in the opposite directions. From the lateral division flows water with the alkalies in solution. The acids remain in the juice and to be eliminated must be especially treated. There follows a filtration and the juice is made to circulate in another battery of very much the same kind, but having the positions of the poles reversed. The water in this case removes the acids.

One of the most practical and interesting methods of juice epuration is the Baudry-Charitonenko process, practically experimented with in France, having been tested on fresh juices, syrups and swing-outs. The object in view was to obtain a thorough epuration as economically as possible, thus supplanting the existing methods of single, double or triple carbonatation. The operation was conducted in the following manner: To the raw diffusion juices leaving the measuring tank was added a very small quantity of a compound containing sulphurous acid, the object being to transform into neutral sulphides the organic potassic and sodic combinations, which are only moderately influenced by electricity. The juice was slightly limed and then continuously forced into the electrodialyzers. These vats are rectangular in shape, and divided into a certain number of compartments, containing alternately the raw juice to be treated and water intended to receive the elements eliminated by the electrical treatment. In these different compartments are metallic disks, having a slight rotatory motion and receiving the current of electricity from a special dynamo; the epuration commences as soon as the current passes. The basic impurities (potassic, sodic and ammoniacal) gradually pass into the water in which are placed the cathodes. The acid impurities in part combine with the metal of the anode which dissolves under the influence of electrical energy.

Owing to the preliminary treatment to which the juice was submitted—namely, the sulphurous compound mentioned in the foregoing—there is a certain economy of electricity. The juices on leaving the electrodialyzers are very clear and well decolorized, retaining at the same time a slight green color; their purity is about 95. A greater purity could be obtained by prolonging the period of electrical treatment, but the cost would be greater than the ad-

vantage gained. To get rid of the green color retained by the juice it is sufficient to add 0.4 per cent of lime, which is subsequently precipitated by carbonic acid gas; the saturation lasts but a few minutes. The juices obtained filter with great ease, and after evaporation the syrups are again subjected to the treatment.

After the concentrated juice leaves the third compartment of the quadruple effect it is sulphured until all the organic acids are liberated without there being the least apprehension that even a slight excess of sulphurous acid might remain, as the temperature of the syrup is not higher than 40° C. The syrups are sent into the negative compartment of the electrodialyzer, where the acids are transported through the agency of the electrical current into the water compartment. The liberated hydrogen from the electrical dissociation of water accumulates at the cathode in the syrup containing the sulphides and free sulphurous acid, and there follows a formation of a new compound known as hydrosulphurous acid, possessing great decolorizing properties. As this chemical possesses great precipitating powers the albuminoids are slightly precipitated and may be separated by filtration. It is important to note that this syrup treatment demands only a very slight expenditure of energy. Upon general principles the rôle played by the electricity in the BAUDRY mode is simply that of a carrying agent for the liberated acids. The expenditure of electricity per hour is 250 watts per hectoliter of raw juices treated. The average purity of raw juices being 0.82, it becomes 0.94 after treatment. Consequently a factory working 500 tons of beets per diem should expend 62,500 watts, or practically a 100-H.P. engine to work the dynamos. If it is intended to epurate the syrups as they leave the compartment before the last of an evaporating apparatus the expenditure of electrical energy is very slight—only 3,500 watts, or 6 to 7 H.P.

In the JAVAUX, GALLOIS and DUPONT process the juices circulate successively in the different electrodialyzers when they come in contact with the different metal electrodes. The juices are rendered alkaline, freed of a portion of their organic substances by a small addition of baryta, and then pass successively through three electrodialyzers in which the anodes are (1) agglomerated magnesia oxide, aluminium or lead, or a combination of the three substances; (2) lead, and (3) iron, aluminium or zinc. When the operation is completed nearly all the soda has been separated in the negative waters, and nearly all the acids and the organic substances, with the exception of the sugars, are precipitated. It

is claimed that the purity of the juice thus treated may be 99.5, and, furthermore, that there are no sugar losses. The selection of the anodes is justified on the ground that some organic lead salts are soluble, while those of magnesia and aluminium are not. Certain changes have been suggested which it is thought would lead to better results. Instead of using electrodes consisting of iron of the best quality, it is proposed to use very inferior iron for the purpose. After the electrodialysis the juices are filtered and then concentrated in the multiple effect. The alkaline waters at 4° to 6° Bé. are used just as they are for fertilizing purposes. They may be evaporated with a view to potash extraction. The SAY-GRAMME Society, who own these patents, have them in practical use in their 800-ton cane-sugar Egyptian factory at El Hawamdieh, and also in a German factory. To work 250 tons of beets per diem a 250-H.P. engine is needed. It is claimed that the quantity of sugar remaining in the residuum molasses is one-fifth of that found by any other known process for sugar extraction.

Among the methods which appear destined to come into practical use is the KOLLREPP and WOHL * electrical process for beet-juice epuration. To the diffusion juices is added about 0.3 per cent of lime, which is precipitated with carbonic acid or any other slightly acid agent, and the juice is then filtered. This preliminary filtration has for its object the elimination of the greater part of the insoluble substances in the alkaline solutions. To the clear filtrate is added 8 to 10 per cent of moist saccharate of lead (containing 50 per cent of water). The liquor is kept in motion by the use of a pump, and the electrodialysis is carried on at 60° C. The positive electrode consists of carbon, and the negative of iron, the diaphragm being parchment paper. The distance between the electrodes is 2 to 3 cm. The electromotive force of the current is 8 to 10 volts, and its intensity per square decimeter is 1½ amperes at the beginning, and one ampere towards the end.

The motive power necessary is about 10 H.P. per 100 liters of juice worked per diem. The epuration is completed when the filtrate from a juice no longer gives a precipitate with lead acetate. The 0.1 per cent of lead remaining in the juice is eliminated ith lime and carbonic acid by the usual methods of working. The moist precipitate of the non-sugar with the lead obtained during electrolysis is mixed with two or three times its weight of

* D. Z. I., 27, 1280, 1902.

caustic potash (8.5 per cent, or of caustic soda, 6.5 per cent) at a temperature of 50° to 55° C. To epurate after-products, these should first be diluted to 20° to 30° Brix. and filtered; the quantity of moist lead to be added is about 40 to 50 per cent of the weight of sugar.

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